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ABSTRACT

Intended as a chapter in "Carmichael's Manual of Child Psychology," this paper provides an overview and interpretation of the work already completed on children's learning, remembering, and understanding with a major concentration on academic cognition. The first part of the paper provides a brief overview of the principal trends of the 1970s and a statement of the advances in the understanding of children's learning that were made during that period. A second section contains a selected review of the literature that highlights the interactive nature of learning. The literature is organized within a framework referred to as the tetrahedral model through which the activities and characteristics of learners in response to variations in criterial tasks and stimulus materials are considered. A third section examines some of the controversies surrounding metacognition and other concepts such as executive control and self-regulation, while the final section concentrates on intervention research and the importance of considering instructional effects when formulating basic developmental theory. (HOD)

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CENTER FOR THE STUDY OF READING

Technical Report No. 244

LEARNING, REMEMBERING, AND UNDERSTANDING

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This paper is to appear as a chapter in the 1983 edition of Carmichael's Manual of Child Psychology, edited by Paul Mussen. The manual will be divided into four volumes. This chapter will appear in Volume 1, Cognitive Development, edited by John Flavell and Ellen Markman. Throughout the text, references are made to other chapters in that volume, notably one on Representation by Jean Mandler and one on Piagetian Concepts by Rochel Gelman and Reneé Baillargeon. There are also references to a chapter by Carol Dweck that will appear in the companion volume on Social Development, edited by Mavis Hetherington, and to chapters by Bob Siegler and the Laboratory of Comparative Human Cognition that will appear in the companion volume on Theories and Methods, edited by Bill Kessen. All four volumes are scheduled for publication in 1983 by Wiley.

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I. Introduction

A. Scope of Chapter

It seems somewhat perverse to begin a chapter, particularly one of this length, with details of what will not be included. But the title of learning, remembering and understanding affords such an open-ended task that we felt it necessary to limit quite stringently the boundaries of the domain we would cover. Given the length of the chapter some might question whether we were stringent enough!

In the section of the previous Handbook devoted to cognitive development, there were two chapters on learning, one on reasoning and thinking, and one on concept development -- but none on memory. In contrast, despite the somewhat catholic title of this chapter, the main data base we will review can broadly be termed "memory research," although by memory we include understanding as well as rote recall; and we will be concerned with acquisition mechanisms in a variety of domains that would not traditionally be included in a chapter on memory. This emphasis reflects the gradual change in the late sixties and seventies away from a concentration on learning mechanisms in a traditional "learning theory" sense towards a consideration of remembering, learning and understanding within a more eclectic framework. At the end of the sixties, a great deal of work was conducted on children's learning, but during the seventies the main emphasis shifted to memory research. We will argue that at the end of the seventies and into the eighties, the focus will again be on learning mechanisms, but this time guided by a cognitive theory of learning that draws its theoretical insights and empirical support from much wider domains than was previously the case.

For a variety of reasons, not least of them being space restrictions, we chose to concentrate on what might be called academic cognition, which differs from everyday cognition along three main axes -- effortful-effortless, individual-social, and cold-hot. Everyday cognition is relatively effortless, social, and hot. Bleak though it may sound, academic cognition is relatively effortful, isolated, and cold.

Academic cognition is effortful because the primary focus is on deliberate and often painful attempts to learn. It is demanding of cognitive efficiency; it takes time and effort. Academic cognition is also relatively isolated because it is concerned with how individuals come to be capable of learning on their own. Although a great deal of learning is social, schools measure success largely in terms of independent competence. Finally, academic cognition is cold in that the principal concern is with the knowledge and strategies necessary for efficiency, with little emphasis placed on emotional factors that might promote or impede that efficiency. Although all these barriers are weakening, a great deal of work in cognitive development can be subsumed under the effortful, isolated and cold categories; and we will confine ourselves primarily to a review of this work. We were, however, somewhat uneasy with the decision to follow these traditional separations for it does force us to neglect some areas where fascinating new research is being conducted. But as we interpreted our task in this chapter, it was (1) to provide an overview and interpretation of the work already completed on children's learning, remembering and understanding, and the vast majority of that work has been on academic learning, and (2) to complement other chapters in the handbook.

Excellent treatments of effortless, social and hot cognition do appear elsewhere in these volumes. The importance of environmental factors, particularly other people, on the forms and functions of human learning is discussed at length in the Laboratory of Comparative Human Cognition (LCHC) chapter in a companion volume of this handbook. Similarly, Dweck (companion volume) gives an in-depth treatment of emotional factors involved in learning effectiveness. And Mandler (this volume) deals with scripted learning which guides a great deal of our day-to-day concourse with the world. The early emergence of powerful scripted knowledge permits much everyday cognition to be relatively effortless and undemanding of cognitive resources, in contrast to the labor-intensive state often required in academic learning situations. Although we do deal with social and emotional factors in the latter part of the chapter, in keeping with our declared focus, we look at these primarily in terms of how they promote effective academic learning.

Even within our restricted focus, this chapter will not represent a review of the literature. First, this would be impossible because the majority of experimental work in cognitive development in the seventies was concerned with memory or learning in the broad sense, and there is just too much to cover. Second, this would be unnecessary, as previous reviews of the topic are legion; predating this chapter are more than 60 quite complete treatments, and an excellent book (Kail & Hagen, 1977). Instead, we have chosen to select for consideration areas of research that illustrate some key theoretical questions and the two basic themes of the chapter, the interactive nature of learning and the dynamic nature of learning.

B. Plan of Chapter

The chapter is divided into four main sections. Section II is a brief overview of the principal trends of the seventies and a statement of the quite dramatic advances in our understanding of children's learning that were made during that period. Section III is a selected review of the literature that highlights the interactive nature of learning. The literature is organized within a framework we refer to as the tetrahedral model through which we consider the activities and characteristics of learners in response to variations in criterial tasks and stimulus materials. In Section IV, we deal with some of the controversies surrounding metacognition and other concepts with which it shares a family resemblance. In Section V, we concentrate on the implications of work in this area for instruction, and the importance of considering instructional effects when formulating basic developmental theory. As this chapter is so long, we have attempted to write each section in such a way that, although there is repeated cross-reference across sections, it is possible for the reader to understand each section in isolation from the others.

II. Major Trends in Research and Theory between 1970 and 1980

As a chapter on children's learning, this paper is the historical descendant of those of Stevenson (1970), White (1970), and to a lesser extent Berlyne (1970) in the preceding handbook; and the reader is referred to these excellent works for continuity. In this section, we will argue that several fundamental changes, already heralded in the Stevenson, White, and Berlyne chapters, occurred in the study of children's learning in the past decade. Under the influence of American learning theory, the dominant metaphor that was extended to children during the sixties was that of a

passive organism responding to enviromental influences. Gradually, the metaphor became that of an active organism, with the child seen as acting upon the environment, and through this action defining it, a metaphor of the genetic approach that White (1970) contrasted with learning theory approaches to children's learning. Throughout the seventies the emphasis shifted to the learner's side of the learner-environment equation, and a heavy concentration on learners' activities and strategies was a prime characteristic of the decade.

A second major change in the decade was in the nature of the materials that children were set to learn; this change resulted in a reconsideration of knowledge factors. Compatibility between prior knowledge and new learning, together with issues of access to and use of knowledge, became prominent concerns. Another change that followed from the liberation of the concept learning from its traditional boundaries was that essential developmental questions of qualitative growth and change became a main focus of discussion. And, finally, epistomological boundaries that separated "learning theory" approaches from, for example, the "genetic" approach (White, 1970) were considerably weakened: psychologists from quite disparate backgrounds became concerned with essentially similar issues. These changes in emphasis had a dramatic effect on the kind of "childrens' learning" considered, the methods by which it was examined, and the developmental theories it generated.

Munn (1954) in an earlier version of the Handbook summarized the "state of the art" in children's learning somewhat depressingly:

> "so far as discovering anything fundamentally new concerning the learning process, the investigations on learning theory in children have failed. One possible reason for this is that such investigations have from the first been patterned too much after

> the lines of earlier research with animals and adults in the laboratory. A more likely reason, however, is that the phenomenon of learning is fundamentally the same whether studied in the animal, child, or adult." (Munn, 1954, p. 449)

The dominating learning theories at the time were those of Hull (1943), Tolman (1932) and Skinner (1938) and, indeed, Munn was in accord with their existing belief in the species-independence of the main principles of learning. Although the critical differences between these theories were sufficiently compelling to occupy empirical psychology for thirty years, they also share common features that make them less than ideal models for developmental psychology. All derived their primary data base from rats and pigeons, learning arbitrary things in arbitrary situations. All three hoped that their systems would have almost limitless applicability. True to a creed of pan-associationism, they shared a belief that laws of learning of considerable generality and precision could be found, and that there were certain basic principles of learning that could be applied uniformly and universally across all kinds of learning and all kinds of species. These principles were thought of as species-indifferent, activity-indifferent and context-indifferent (Brown, 1982; Turvey & Shaw, 1979).

The theories had very little to say about species variation. Attempts were made to place animal species (also humans differing in age) on a ladder of increasing intellectual capacity. For example, fish were designated less intelligent than rats because they display less of a certain type of learning (Bitterman, 1965). The skills selected as measures of intelligence were quite arbitrary (species independent), as indeed were the situations selected in which to test the presence/absence of the skills (e.g., impoverished environments where the skills to be

learned had no adaptive value for the species in question). In summary of this type of enterprise, it has been said (Schwartz, quoted in Rozin, 1976) that by studying the behavior of pigeons in arbitrary situations we learned nothing about the behavior of pigeons in nature, but a great deal about the behavior of people in arbitrary situations.

Of more importance to this chapter, the theories had very little to say about developmental issues. The growth of the knowledge base was simply incremental. Although later there were some attempts to deal with reorganization of small basic units into larger complex forms, it was by no means dominant in these theories, and by no means an unqualified success. Children learned by the same rules as adults (or pigeons for that matter) and the result of experience was seen as an accumulation of associations varying in strength, with strength determined by the amount and recency of reinforcement/contiguity relations. In short the theories did not confer special status to age or species differences, and thus provided a somewhat unlikely metaphor for those whose primarily goal is to understand human growth and learning (Brown, 1982; Rozin, 1976; White, 1970).

Munn's theme was repeated in both the Stevenson and White chapters on learning that appeared in the 1970 Handbook. Both agreed that "research on children's learning is for the most part a derivation of psychological studies of learning in animals and human adults" (Stevenson,, 1970, p. 849). And that "no learning theory has even been constructed from studies of children or been specifically directed toward them. Strictly speaking, there in no learning theory in child psychology" (White, 1970, p. 667). Note that in so stating, White contrasts the "genetic approach" of Piagetian, Wernerian and Soviet origin with "learning theory," a commonly accepted division before this decade.

Children's learning became included in the bailiwick of learning theories because its proponents adopted the specialized methods common to investigations of learning in animals.

> "In most of the specialized procedures, the subject's time to observe or act is partialed out in trials. The time and place of learning is fixed and the environment is isolated, uninterrupted, and asocial. Discrete cues are made prominent. Criteria, set up by observer or instrument, are enforced so that countable, timeable, scorable responses are fished from the stream of behavior. These typical research procedures for the study of learning have regularized it, made the learning situation more repeatable across individuals and laboratories. The (dominant) theories of learning were based upon the possibilities of controlled variation and experimentation possible when learning had been so regularized." (White, 1970, p. 667)

And a great deal of progress was made in systematizing the study of children, by subjecting them to learning tasks developed originally for the investigation of animal learning. Many of the main headings in Stevenson's review reflect this influence: conditioning, drive level, delay of reward, stimulus familiarization, stimulus generalization, satiation and deprivation, extinction, secondary reinforcement, discrimination learning, learning sets, oddity learning, transposition, reversal-nonreversal shifts, were all studied originally with animals. Stevenson and White provide extensive reviews of the great deal of information that was gathered from a consideration of children learning in those settings. This was a prolific period of research and we gained a great deal of information of lasting value, especially concerning selective attention (Zeaman & House, 1963), symbolization (Berlyne, 1970; Kendler & Kendler, 1962; Reese, 1962), hypothesis testing (Levine, 1969), curiosity and exploration (Berlyne, 1970), learning sets (Harlow, 1959; Reese, 1968), stimulus differentiation (Tighe, 1965), social learning (Bandura & Walters, 1963) and behavioral engineering (Bijou & Baer, 1967; Lumsdaine & Glaser, 1960; Skinner, 1971).

While Munn in 1954 seemed quite content with the age and species independence of learning principles, Stevenson and White reflected the concern during the sixties with species differences, and particularly age differences in learning, which they review extensively. But, furthermore, in both chapters one senses the beginning of a dissatisfaction with the types of learning investigated and their potential contribution to a developmental theory of learning. For example, Stevenson questions whether the principles of learning gained in the confines of the traditional laboratory task will hold up in a variety of settings, particularly those of a social or "everyday" nature. White queries whether "these experimental situations and their variations offer too narrow a window through which to explore the underlying developmental process" (White, 1970, p. 671). Further, White calls for a consideration of mechanisms of age change rather than just descriptions of "before and after the learning process," all themes that are current today.

White contrasted the learning theory approach to that of the genetic tradition, always attractive to developmental psychologists, but supplanted for a while because of the sheer elegance of the models and methods of learning theory at a time when "the transcription of the genetic point of view into a rigorous and tough-minded program for maintaining and continuing research" had not taken place (White, 1970, p. 663). These approaches were seen as essentially incompatible and a merger impossible unless basic tenets were abandoned or softened to permit an accomodation. We will argue that the seeds of such a merger were planted and did come to fruition in the seventies. Next we will consider some of the shifts in emphasis that could at least enable a merger even if not actually bring it about.

One legacy of the learning theory approach was that of an essentially passive organism (see Reese, 1973, 1976 for a discussion of this methaphor). To improve learning from this perspective one would not try to change the learner, one would change the stimulus environment to which the learner is responsive. For example, one might improve learning by increasing the number, immediacy and/or quality of the reinforcement, or one might vary the type or saliency of the stimulus dimensions, etc. There is nothing wrong with this approach; apart from anything else, it works, learning improves. But the focus is heavily directed to one side of the learner-context interaction. During the late sixties and early seventies this focus shifted with the learner's activities receiving the lion's share of attention. Influenced by European (Flavell, 1963; Hunt, 1961) and Soviet (Cole & Maltzman, 1969) genetic traditions, and by the landmark work of Bruner (Bruner, Goodnow & Austin, 1956; Bruner, Olver, & Greenfield, 1966) and Flavell (1970a), attention turned to the child's strategies for learning.

One reflection of this shift is that by the middle seventies, developmental journals were dominated by studies of children's knowledge and use of strategies, particularly those devised in the service of deliberate remembering. As many reviews predate this chapter (for example, Belmont & Butterfield, 1977; Brown, 1974, 1975, 1978; Flavell, 1970a; Hagen, Jongeward & Kail, 1975; Kail & Hagen, 1977; Meacham, 1972; Ornstein, 1978), we will not review this work in detail. Suffice it to say that a major contribution of the seventies was the impressive body of knowledge generated on the subject of the development of active acquisition strategies of learning, such as rehearsal (Atkinson, Hansen, & Bernbach,

1964; Belmont & Butterfield, 1971; Bray, 1973; Brown, Campione, Bray & Wilcox, 1973; Flavell, Beach, & Chinsky, 1966; Hagen, Hargrave, & Ross, 1973; Hagen, Meacham & Mesibov, 1970; Hagen & Stanovich, 1977; Keeney, Cannizzo, & Flavell, 1967; Kingsley & Hagen, 1969; Ornstein & Naus, 1978), categorization (see Mandler, this volume, for a review; also Moely, 1977; Puff, 1979), and elaboration (Borkowski & Wanschura, 1974; Borkowski, in press; Jensen & Rohwer, 1963; Rohwer, 1973; Turnure & Thurlow, 1973), and retrieval mechanisms (Buschke, 1974; Kobasigawa, 1974, 1977; Keniston & Flavell, 1979; Ritter, Kaprove, Fitch & Flavell, 1973), together with the child's developing knowledge and control of her repertoire of strategic action, i.e., metacognition (Borkowski & Cavanaugh, 1979; Brown, 1975, 1978, in press b; Butterfield & Belmont, 1977; Butterfield, Siladi, & Belmont, 1980; Campione, in press b; Campione & Brown, 1977, 1978; Flavell, 1971a, 1976; Flavell & Wellman, 1977; Wellman, in press).

A second major change that was consolidated during the seventies was in the type of materials children were required to learn. Prior emphasis on color-form stimuli, nonsense syllables and words and pictures in isolation, was supplanted by a focus on organized or potentially organizable material (see Mandler, this volume, for a review). Children in the seventies were asked to learn picture sequences (Brown, 1975, 1976; Brown & Murphy, 1975; Day, Stein, Trabasso, & Shirey, 1979; Horowitz, Lampel, & Takanishi, 1969), sentences (Paris & Lindauer, 1977), stories (Brown & Smiley, 1977; Brown, Smiley, Day, Townsend & Lawton, 1977; Mandler & Johnson, 1977; Stein & Glenn, 1979; Stein & Trabasso, in press; Trabasso, Stein & Johnson, in press; see Mandler, this volume, for a review), and expository texts (Brown & Day, in press; Brown, Palincsar, & Armbruster, in press; Markman, 1979).

Perhaps an even more dramatic change was in the subject matter to be learned, for toward the end of the decade children as well as adults were examined as they attempted to learn in semantically rich domains, such as chess (Chi, 1978), physics (Larkin, Heller & Greeno, 1980), mathematics (Resnick, 1976), and history and social sciences (Voss, in press). With these shifts in emphasis, questions about the knowledge base also changed from a consideration of the accumulation of facts and their reinforcement histories, to a consideration of the organization and coherence of information, along with the compatibility of new information to prior experience (Brown, 1975; Paris & Lindauer, 1977). Providing an inspiration for this trend in the developmental literature was the work of Bransford and Franks (see Bransford, 1979) with adults and the work on contextual sensitivity of learning generated by cross-cultural psychologists (for recent reviews see the Laboratory of Comparative Human Cognition, in press a,b and Rogoff, 1981).

The third major change that occurred during the seventies is that to some extent, the boundaries that were clear in the chapters of the 1970 volume were weakened in the movement toward a cognitive theory of learning. To illustrate we will give a brief and oversimplified description of the major trends in the seventies as reflected in publications in the developmental journals.

The beginning of the seventies saw the formation of a somewhat uneasy alliance between developmental psychologists trained in the tradition of neo-behavioral learning theories and their descendants, information processing models, and psychologists influenced by the traditional developmental schools such as those of Piaget and Werner. This alliance was forged through a common interest in learning strategies.

Information processing psychologists, deeply influenced by the prototypic memory model of Atkinson and Shiffrin (1968), began to emphasize the importance of control processes, i.e., strategies and routines for making more efficient use of a limited capacity information processing system. Such common control processes as rehearsal received considerable attention. Typical of this approach in developmental psychology was the work of Belmont and Butterfield (1971, 1977), Brown and Campione (Brown, 1974; Brown, Campione, Bray & Wilcox, 1973; Campione & Brown, 1977), Hagen (Hagen & Stanovich, 1977) and Ornstein and Naus (1978).

Contemporaneous with this work, influenced primarily by John Flavell's pioneering efforts, cognitive developmental psychologists became interested in memory strategies, defined as deliberate planful activities introduced in the service of remembering. Following the landmark paper of Flavell, Beach and Chinsky (1966), rehearsal mechanisms again received the lion's share of attention, followed closely by organization and elaboration. Together, developmental psychologists from both backgrounds provided a rich description of the development of mnemonics for learning common laboratory (and often school) material. Thus, developmental psychologists originally influenced by the dominant adult approaches and those initially influenced by Piaget, all became interested in the activities of the learner and in the acquisition of principled rules and strategies (Gelman & Gallistel, 1978; Siegler, 1976).

The result of these shared interests was a common concern with production deficiencies, a term originally introduced in the context of learning theories (Kendler, 1964; Reese, 1962) and adopted by Flavell, Beach and Chinsky (1966). Flavell (1970b) extended the concept "beyond the

simple cue-producing responses to which it had been limited in Hull-Spence theory and applied it to mnemonic strategies and other complex cognitive operations -- making it much more consistent with Vygotsky's usage" (Reese, 1979; for a recent discussion, see Paris, 1978). In short, from a variety of backgrounds, developmental psychologists became interested in the use of strategies, whether naturally evolved or deliberately trained. This led the information processing group to embark on a series of training studies in order to examine whether children's memory deficits were largely the result of inefficient use of control processes or structural limitations to the system (a problematic theoretical distinction; see Belmont & Butterfield, 1977 and Brown, 1974). Meanwhile, Flavell (1970b) and his co-workers were concerned with a very similar issue: Do children fail to use strategies 1) because they do not think to, or 2) because strategies will not help, or 3) because children cannot use them. Neo-Piagetians were also concerned with training studies as a method of revealing competencies often obscured by performance factors (see Flavell, 1970b, and Gelman & Baillargéon, this volume, for a history of this debate).

Thus, one reason for a merger was methodological. Training studies were employed by psychologists from diverse backgrounds to address questions about the nature of developmental change. Regardless of the theoretical impetus, the results of this spate of studies are clear. Briefly, immature learners tend not to introduce strategies to aid their learning. They can, however, be trained to do so and their performance dramatically improves when they receive such instruction. Unfortunately, it also became clear that in the absence of specific instructions the immature learner rarely uses such strategic activities intelligently, even following

relatively explicit and extensive training (Belmont & Butterfield, 1977; Brown, 1974, 1978; Brown & Campione, 1978; Butterfield et al., 1980; see Section V). Similarly, competencies of young children uncovered by workers in the genetic tradition (see Gelman, 1978) were also shown to be extremely fragile (Flavell, 1982).

The dramatic failure of training studies to effect major changes in the intelligent use of strategies was a main feature of research in the middle seventies and provided a prime impetus to the growth of the concept metacognition (see Section IV). Impressed by the pervasive nature of production deficiencies, Flavell and his colleagues became interested in children's awareness of their own memory processes and the subject, task and strategy variables that influence learning (Flavell & Wellman, 1977). It is this form of self-knowledge that Flavell dubbed metamemory (Flavell, 1971a). The information-processing group also began to concentrate on issues of executive control, long a cause of theoretical controversy within their models. The executive is imbued with a wide range of overseeing functions including predicting, monitoring, reality-testing and the coordination and control of deliberate strategies for learning (Brown, 1978); and it was in performing these executive routines that young children experienced difficulty. The work of Belmont and Butterfield (1977), Brown and Campione (Brown, 1975, 1978; Brown & Campione, 1981) and Borkowski (in press) are good examples of this approach. Failures to plan, monitor, and oversee were thought to be in large part responsible for transfer failures in the young, as was the lack of relevant declarative knowledge concerning the domain memory. These somewhat separable forms of metacognition -- a) executive control and b) declarative knowledge -- were

examined extensively in the later part of the decade. Similarly, Piaget and his colleagues (Piaget, 1976, 1978; Inhelder, Sinclair, & Bovet, 1974; Karmiloff-Smith & Inhelder, 1974/75; Karmiloff-Smith, 1979a,b) also became increasingly concerned with the twin forms of metacognition, self-regulation during learning and conscious control of the learning process. Despite some thorny theoretical confusion, there is considerable agreement concerning the young child's peculiar difficulties in this domain (see Sections IV and V).

Toward the later part of the seventies, points of common interest so far outnumbered original differences that the old barriers between learning theorists and cognitive development theorists were no longer viable. The common interest in strategies and their control, never a major concern in the adult literature, weaned a great many developmental psychologists from their dependence on adult models and paved the way for a merger between those from the genetic tradition and those whose training had been primarily influenced by dominant adult models. From all directions came a concern for developing a cognitive theory of learning that would give a central place given to the developmental issues of growth and change (Brown, 1979, 1982).

Janus-faced at the onset of the eighties, developmental psychologists seem to be in remarkable agreement concerning the major advances in the seventies and the key questions facing the construction of a cognitive learning theory in the eighties. First it is increasingly clear that the model will be essentially interactive. To illustrate this point, we have chosen to organize our review of the literature around a tetrahedral interactive learning model introduced by Jenkins (1979). To understand

learning, it is necessary to consider both subject (activity, prior knowledge, capacity, etc.) and environmental factors (task demands, materials, contexts, etc.) as well as the state of mutual compatibility between them.

A second major issue that has an honorable history is that of stages versus continuous age changes in acquisition (see Brain and Behavioral Sciences, 1978, Volume 1(2); plus Brown, 1982; Case, 1981; Feldman, 1980; Fischer, 1980; Flavell, 1971b, 1982; Gelman, 1978; etc. for recent reviews of this question). One current instantiation of this traditional topic is the question of accessibility of knowledge (Brown, 1982; Brown & Campione, 1981; Gelman & Gallistel, 1978; Rozin, 1976). The prime question concerns the fragility of early competence versus the robust transsituational nature of mature forms of the same skill. In an influential paper on the topic of access, Rozin (1976) made two main points. First is the notion of welding (Brown, 1974; Fodor, 1972; Shif, 1969); intelligence components can be strictly welded to constrained domains, i.e., skills available in one situation are not readily used in others, even though they are appropriate. Quite powerful computational processes may be available to the very young child, but only for the performance of quite specific types of computations (Fodor, 1972). Rozin argues that young children's programs are "not yet usable in all situations, available to consciousness or statable" (Rozin, 1976, p. 262). Development is "the process of gradually extending and connecting together isolated skills with a possible ultimate extension into consciousness." The second part of both the preceding quotes refers to Rozin's second main point, that of conscious access. Even if skills are widely applicable rather than tightly welded, they need not necessarily be

conscious and statable. Conscious access to the routines available to the system is the highest form of mature human intelligence (see Section IV).

Pylyshyn (1978) made a similar distinction between multiple and reflective access. Multiple access refers to the ability to use knowledge flexibly. Knowledge is informationally plastic in that it can be systematically varied to fit a wide range of conditions. Reflective access refers to the ability to "mention as well as use" the components of the system. Similarly, Gardner (1978) cites as hallmarks of human intelligence (a) generative, inventive, and experimental use of knowledge rather than preprogrammed activities (multiple access) and (b) the ability to reflect upon one's own activity (reflective access). The twin concepts of flexibility and reflection are important issues with wide implications for theories of learning and development, and they will be a main theme of this chapter (see Section IV and V).

Finally, a main theme of the chapter which we believe will be the principal question of the eighties is that of mechanisms of growth and change. A basic problem in understanding learning is to explain how the learner progresses from knowledge gained in specific learned experiences to the stage when she can use knowledge flexibly. This is the question behind access theories -- how do isolated skills become connected together, extended and generalized (Brown & Campione, 1981; Rozin, 1976)? Development is the process of going from the specific context bound to the general context-free, although truly general, context-free, statable laws may be a chimera, an idealized end point. Knowledge in some sense must always be context bound, but contextual binding permits of degrees. It is the range of applicability of any particular process by any particular

learner that forms the diagnosis of expertise or cognitive maturity. The less mature, less experienced, less intelligent suffer from a greater degree of contextual-binding, but even the expert is bound by contextual constraint to some degree (Brown, 1982). Thus, a key developmental question is how children go from strict contextual binding to more powerful general laws. One commonly suggested mechanism is conflict -- conflict induces change, a notion basic to learning theories (Berlyne, 1970), dialectic theories (Wozniak, 1975) as well as Piagetian models (Inhelder, Sinclair, & Bovet, 1974). A serviceable hypothesis is maintained until a counterexample, an invidious generalization, or an incompatible outcome ensues. Conflict generated by such inconsistencies induces the formulation of a more powerful rule to account for a greater range of specific experiences (see Section IV).

Brown (1982) described three methods that developmental psychologists are beginning to use widely in order to attack the problem of development head-on. The first method is to provide as rich and detailed a description as possible of the qualitative differences in both factual and strategic knowledge between young (novice) and older (expert) learners (Chi, 1978, 1981; Siegler, 1981; see also Section III). Based on this information, it is then possible to address the transition process directly by observing learning actually taking place within a subject over time. This is essentially the microgenetic approach advocated by Vygotsky (1978) and Werner (1961). The majority of developmental data to date has been cross-sectional. The performance of groups of children, varying in age or level of expertise, is compared and contrasted. Even a great deal of longitudinal research has a surprisingly cross-sectional flavor in that we

tend to see frozen shots of behavior taken at quite long intervals. Both approaches provide a picture of cognition in stasis rather than evolving, as it were, right before one's eyes. The revived interest in microgenetic analysis of both adult (Anzai & Simon, 1979) and children's (Karmiloff-Smith, 1979a,b) learning enables psychologists to concentrate not only on qualitative descriptions of stages of expertise but also to consider transition phenomena that underly the progression from beginning to expert states. As we come to understand more about qualitative descriptions of the stages of expertise, and of the mechanisms that seem to induce change, the third approach is made possible, that is to attempt to understand change better by engineering it (see Section V). Each approach serves a complementary function in contributing to our knowledge about learning processes. As a result of such an attack, we should become better able to: a) describe the stages of development, i.e., model developmental progressions and trajectories within a domain; b) model self-modification processes in individual learners acquiring expertise; and c) engineer transition by the provision of appropriate experience. If so, we must come to understand better the essential elements of learning. Armed with such understanding we would be in a better position to help the less mature acquire the appropriate self-awareness to enable them to learn how to learn (Section IV and V).

Central themes of this chapter are, then, acquisition of information, access and use of knowledge, and transition mechanisms that are involved in change. We argue that the learning model that will be necessary to incorporate these themes will be an interactive model. Redressing earlier unbalanced treatments that were either heavily learner-centered or heavily

task-centered, the interactive models of the eighties will be primarily concerned with learner-task compatibility. We would like to emphasize, however, that it is only because of the exponential increases in our knowledge concerning activities, knowledge, materials, and task variations in relative isolation that we are in the current position of preparedness to attack the complexity of interactive models, the subject of our next section.

III. A Tetrahedral Framework for Exploring Problems of Learning

The majority of developmental memory research conducted in the late sixties and throughout the seventies led to the establishment of a fairly detailed picture of how the child becomes a school expert, i.e., how the young learner acquires academic skills and comes to know how to learn deliberately. To illustrate the current state of our knowledge, we would like to introduce the diagram in Figure 1, which we borrowed from Jenkins (1979) and have used liberally in several publications (Bransford, 1979; Brown, in press a; Brown, Campione & Day, 1981). At first glance this

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Insert Figure 1 about here.

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seems like a simple model, particularly in comparison with the elaborate flow diagrams favored by modern cognitive psychologists who were imprinted on the computer in their formative years. Unfortunately, as is often the case in psychology, the simple model becomes more complex on closer examination. It does, however, provide a useful aid to help us remember the major factors that should be taken into account when considering any aspect of learning. We would like to stress that not only should we, the

psychologists, consider the tetrahedral nature of the learning process, but this is exactly what expert learners come to consider when they design their own plans for learning (Flavell & Wellman 1977, and see Section IV on metacognition).

There are a minimum of four factors that comprise the learner-in-context, and these factors interact in nontrivial ways. The four factors are (a) the learner's activity, (b) the characteristics of the learner, (c) the nature of the materials to be learned, and (d) the criterial task. Because of the sheer weight of empirical evidence, we will give only a few illustrations of the types of factors that have been considered under each of these rubrics and then provide selected examples of the essentially interactive nature of the model.

A. Learning Activities

The activities that the learner engages in are a prime determinant of efficiency. Some systematic activities that learners use are referred to as strategies, although what is strategic and what is not has not been made particularly clear in the literature. We will concentrate primarily on deliberate plans and routines called into service for remembering, learning or problem solving, although we recognize that a great deal of cognition is not as effortful as this (Brown, 1975; Naus & Halasz, 1979; Hasher & Zacks, 1979).

Strategies are part of the knowledge base and therefore could be classified as a characteristic of the learner within the model. But the learner's activities are not necessarily synonymous with the strategies available in the knowledge base. Learners can access strategies or any other form of knowledge to help learning, but they need not. Having

knowledge, of any kind, does not necessitate using it effectively. In this section, we will concentrate on the systematic application of a plan, routine, or activity designed to enhance learning.

One of the most established facts is the active strategic nature of a great deal of learning in older children. During the sixties and seventies, developmental psychologists provided a rich picture of the development of strategies for learning and remembering as well as quite convincing evidence that efficient performance in a wide variety of tasks is in large part dependent on the appropriate activities the subject engages in, either on her own volition, when trained to do so, or even when tricked into doing so by means of a cunning incidental orienting task. As children mature, they gradually acquire a basic repertoire of strategies, first as isolated task dependent actions but gradually these may evolve into flexible, and to some extent generalizable, skills. With extensive use, strategic intervention may become so dominant that it takes on many of the characteristics of automatic and unconscious processing (Shiffrin & Schneider, 1977). Under instructions to remember, the mature learner employs a variety of acquisition and retrieval strategies that are not readily available to the developmentally less mature individual.

As we stressed in Section II, this is an influential area of developmental psychology where a great deal of progress has been made. We would like to emphasize just how robust the strategy-performance link is by pointing out both the reliability of the finding that increased strategy use leads to increased memory performance and the magnitude of the effect that is due to strategic intervention. For example, there is ample evidence that the extent, consistency and type of rehearsal use is

intimately related to recall efficiency (Belmont & Butterfield, 1977· Ornstein & Naus, 1978). Mature use of a rehearsal strategy following training can increase the performance of retarded children to the level set by untrained adults (Butterfield & Belmont, 1977). Similarly, mature application of an organizational strategy increases recall of college students by a large order of magnitude (Bower, Clark, Lesgold & Winzenz, 1969). The reliability and magnitude of the effect that is due to strategic intervention should not be overlooked.

Although this is one area where psychologists have been successful at providing a rich description of development, there are still some notable holes in the picture. Until recently, there has been a marked paucity of information concerning the early emergence of plans and strategies for learning. Although Flavell and his collegues have always been interested in memory in preschool children (Flavell, 1970b; Wellman, 1977) and although there is currently increasing research activity in this area (Perlmutter, 1980), it is still true that our knowledge about early cognition is somewhat limited and rather negative, consisting of many more descriptions of what young children cannot do, than of what they can do (Brown & DeLoache, 1978; Gelman, 1978).

The problem of defining early competence has been especially acute in the area of memory research. Until recently, the prime concern was with the competencies that define the school-aged child, specifically the shift to more adequate understanding that seems to occur between five and seven years (White, 1965). The bulk of studies during the early seventies concerned rote learning of lists, and the emergence of rehearsal, categorization, or elaboration as tools to enhance performance (Kail &

Hagen, 1977). These strategies tend to emerge in a recognizable form between five and eight years of age. One by-product of this focus is that indeed we do know a great deal concerning the development of classic strategies (rehearsal, etc.) during the grade school years but we know less about the precursors of these strategies. If young children are not, for example, rehearsing on a deliberate memory task, we have no way of knowing what it is that they are doing.

The second gap in our knowledge about strategic development is again due to paucity of data, this time concerning the development of memory and learning strategies after the middle grade school years. There are several excellent programs of research that detail the refinement and elaboration of list learning strategies during the high school years, notably those of Belmont and Butterfield (1971, 1977), Ornstein and Naus (1978), Neimark (1976), and Rohwer (1973); but, until recently there was little attention paid to strategies other than rehearsal, categorization, and elaboration. This question is beginning to be addressed in interesting and exciting ways and we will review some of the recent work on strategic development in adolescents in this section.

A third change in our attack on the strategy development issue has been greater emphasis on the interplay of knowledge factors and strategic action. Although no one denied the importance of knowledge (Brown, 1975; Flavell, 1970b) it has only recently been the subject of extensive empirical investigation (Chi, 1981; Ornstein & Corsale, 1979; Ornstein & Naus, 1978), at least intraculturally. Elegant intercultural demonstrations of the importance of knowledge factors in memory performance (Laboratory of Comparative Human Cognition, in press a,b· Rogoff, 1981) still provide the most extensive empirical support for the position.

As it would clearly be impossible to give a detailed review of the development of strategic learning, and there are many prior sources for perusal by the devotee, we will illustrate this topic with a brief description of one classic example, the development of rehearsal. The remainder of this section will be devoted to the relatively neglected areas of 1) the early emergence of precursors of strategic intervention, and 2) the development of strategies in the adolescent period. Knowledge based issues will be reserved until the section on the characteristics of the learner.

1. A Prototypic Memory Strategy: Rehearsal. Developmental psychologists are not alone in their dependence on rehearsal strategies for theory building. A strong dependence on rehearsal can be found in the proliferation of memory models in the adult literature of the early seventies, and this is true of both the "modal model" (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965; Murdock, 1967) and the "levels of processing" varieties (Craik & Lockhart, 1972). We have chosen rehearsal as our illustration of traditional strategies research, not because we accord undue status to this activity, but simply because the description of developmental processes is particularly rich in this domain.

A typical study of the late sixties and early seventies was one where the relationship of strategy use to memory performance was investigated. Prototypical experiments of this genre consisted of an assessment phase and a training phase (Flavell, Beach, & Chinsky, 1966). It was readily shown that young or slow children tended not to produce mnemonic strategies in the assessment phase but could readily be trained to do so; and, in so doing they greatly improved their memory performance. We would like to

stress that this prototypical finding has been replicated many times and is one of the most robust findings in the developmental literature (Belmont & Butterfield, 1977; Brown, 1975, 1978; Flavell, 1970a; Hagen, Jongeward & Kail, 1975; Kail & Hagen, 1977; Ornstein & Naus, 1978; etc.).

A neat twist on this procedure is that if older students are prevented from using a strategy, for example, rehearsal, they produce levels and patterns of performance that are very similar to younger or slower learners (Belmont & Butterfield, 1977; Brown, Campione, Bray & Wilcox, 1973). These findings were taken as strong evidence in favor of the utility of strategic intervention. Young children trained to rehearse perform like older spontaneous users of the strategy; spontaneous users prevented from so indulging perform like the young children (for limitations on the effects of training, see Section V).

Considerable evidence exists to support a basic presence/absence position; when rehearsal is present the result is good performance, when rehearsal is absent the result is bad performance. However, the presence/absence argument was always bedevilled by confusion as to what rehearsal was and what activities could be counted as rehearsal-like. Thus, in studies where observation (Flavell, Beach, & Chinsky, 1966) or electromyographic recordings (Locke & Fehr, 1970) of lip activity have been used to denote rehearsal, children as young as four or five are credited with strategy use. Evidence of systematic coordination of acquisition and retrieval demands for complex rehearsal plans is not readily apparent until well into the high school years (Belmont & Butterfield, 1977· Ornstein & Naus, 1978; Neimark, 1976).

A thumbnail sketch of the development of spontaneous rehearsal strategies follows a path that could be traced through studies concerned with other acquisition and retrieval strategies (e.g., Keniston & Flavell, 1979; Kobasigawa, 1977; Reese, 1977, Rohwer, 1973; Mandler, this volume). Primitive precursors of rehearsal are preschooler's sporadic attempts to maintain material via naming, pointing or eye fixation (Wellman, Ritter, & Flavell, 1975). By five years of age, children attempt to name (label) some of the items some of the time. Labelling becomes well established during the early grade school years and is a prime example of what has been called maintenance rehearsal (Craik & Watkins, 1973; Cuvo, 1975; Ornstein & Naus, 1978). The prototypical pattern of rehearsal from third graders would be a rote repetition of single items. With increasing sophistication, children begin to employ more items in their rehearsal sets, and hence, are said to engage in cumulative rehearsal (Belmont & Butterfield, 1971). Development during the later grade school and early high school years consists of the continual refinement of a cumulative rehearsal strategy that includes planning of both the acquisition and retrieval components (Butterfield, Wambold, & Belmont, 1973) and increasing attention to the size and composition of the rehearsal set (Ornstein & Naus, 1978). Finally, children begin to produce elaborated rehearsal (the contrast to maintenace rehearsal). They become increasingly sensitive to the presence of conceptual organization in the to-be-remembered list and capitalize on this inherent structure whenever possible (Ornstein & Naus, 1978). Thus, the rehearsal plans of high school children and adults are active, systematic, elaborative procedures, whereas those of younger children are rote maintenance procedures. The systematic refinement of the

rehearsal strategy is gradual; the evolution is not "fully" completed until adulthood, if then. In general, however, college students devise spontaneous rehearsal plans that are readily tailored to meet the specific, and even the changing, demands of the particular task at hand (Butterfield & Belmont, 1977). Finally, even with this supposedly most content-free of all strategies, rehearsal use is intimately related to knowledge and capacity factors (Ornstein & Naus, 1978).

2. Early Emergence of Strategies. In the mid to late sixties developmental psychologists were interested in a phenomenon known as the five-to-seven shift (White, 1965), i.e., did a qualitative change in cognitive functioning occur at the point where children were making the passage to formal schooling (Rogoff, Sellers, Pirrotta, Fox, & White, 1975)? Interest in this question was shown by developmental psychologists with quite diverse backgrounds. Learning theorists disputed whether a qualitative shift occurred between non-mediated learning in the preschooler to mediated learning in the older child (Kendler & Kendler, 1962; Zeaman & House, 1963). Similarly, a shift from absolute to relational learning was contested (Brown & Scott, 1972; Kuenne, 1946; Reese, 1968). At the same time, Piagetians were interested in the qualitative changes that accompany the transition from preoperational to concrete operational thought, also believed to occur between five and seven years of age (see Gelman & Baillargéon, this volume).

It was in this context that the early work on the development of memory strategies was often interpreted as yet another exemplar of the ubiquitous five-to-seven shift. Although Flavell and his colleagues did consider earlier production of strategies (Flavell, Beach, & Chinsky,

1966), there was some question concerning the leniency of the criteria that attributed strategic thinking to the preschool child (Wellman, 1977). For the most part, investigators concentrated on the emergence of the three common strategies: rehearsal, categorization and mnemonic elaboration; and the age trend they found tended to confirm the impression of another five-to-seven shift. Prior to five years of age, children were deemed passive, nonstrategic and nonplanful in memory tasks, just as they were judged to be preoperational, precausal, and egocentric in classical Piagetian tasks, and non-mediated responders in learning tasks.

Recent evidence suggests that in many domains preschool children have more competence than was initially supposed (Gelman, 1978). A successful method for uncovering early competence is to situate the experiment in a manner ideally suitable for the preschoolers' interests and abilities. The idea is to look for evidence of competence, not only in the traditional laboratory tasks, but also in situations where that competence could most readily be shown. To considerably oversimplify the comparative literature, the two major techniques that have been used to expose early competency have been (1) to strip away all but the most essential elements of the task in order to reveal its cognitive demands in the simplest possible form and (2) to situate the experiment in the familiar. A combination of these two techniques marks the better cross-cultural experimental work (Laboratory of Comparative Human Cognition, companion volume) and also reveals early competence in preschool children. For example, Shatz (1978) argued cogently that earlier (or later) competence in communicative situations can readily be accounted for by the "excess baggage" of the task. In unfamiliar situations, with arbitrary stimuli, where the children must

expend considerable cognitive effort identifying the items and comprehending the nature of the game, they appear unable to communicate adequately with a peer. In situations where the game is familiar, the information to be conveyed is meaningful and, therefore, cognitive "capacity" is freed for the communicative aspect of the task, the younger children look far more reasonable; they communicate well. Flavell and his colleagues (Salatas & Flavell, 1976; Flavell, in press) have also shown that complexity and familiarity are important factors leading to a diagnosis of egocentricism in children. Similarly, Gelman and her colleagues (Gelman, 1978; Gelman & Baillargéon, this volume; Gelman & Gallistel, 1978) have made this point quite graphically for several "concrete" operational tasks (for early discussions of these points see Flavell, 1970b and Flavell & Wohlwill, 1969).

A consideration of the memory development research in the seventies also suggests that a gradual progression to competency is more representative than the idealized five-to-seven shift from non-strategic to strategic status. Although full-blown forms of rehearsal, categorization and elaboration are not apparent before five and relatively stable by seven to eight (at least in a recognizable form), it is an illegitimate inference to conclude that, therefore, the propensity to be planful is absent prior to the emergence of these activities. Recent concentration on preschool learners and memorizers has revealed a very early propensity to be strategic in situations where the goal of the activity is clear to the child, the setting familar and the index of strategic use more lenient (Meacham, 1972; Wellman, 1977). We will consider some of this evidence next.

There have been two major approaches to the study of preschool memory. That of Perlmutter and Myers (1979) and their associates is to assume that strategies are largely absent before five years of age and then to find an alternative explanation of why memory on both recall and recognition improves from two to four years. They assume that the improvement is due to increased knowledge, and, of course, they are right. Increases in knowledge are very likely to result in changes in memory performance on tasks that tap that knowledge. Perlmutter and Myers have successfully documented this point. Their evidence concerning the absence of strategies is largely inferential, however, and indeed it is very difficult to distinguish between changes due to strategies and changes that are due to knowledge on a free recall task, a point to which we will return.

The second main approach is to assume that although full-blown versions of rehearsal, categorization, and so on are not likely to be present before seven, early indices of strategic intervention can be found; and they are related to efficiency. Istomina (1975, in research conducted in 1943) provided a rich picture of the gradual emergence of strategies in preschool children. Istomina set children the task of remembering a list of items either to be bought at a play store, or as a "lesson." Recall was superior in the game situation. Istomina argued that the improved memory in the shopping condition followed because the goal of the activity made sense to the child. Although the youngest children knew what it meant to remember, this was not enough: "They must not only know what remembering is by itself, but also be able to see it as an end result, an objective to which activity must be directed, i.e., to grasp it as a goal" (Istomina, 1975, p. 59). Istomina's study produced a delightful set of protocols

detailing individual children's emergent procedures for remembering. The strategies adopted and the way in which they were used became increasingly complex and sophisticated over the age period of four to six.

Two contemporary research programs aimed at the early emergence of planful memory have shown competence at even younger ages than Istomina. Wellman and his colleagues (1977) have been concerned with engineering situations in which evidence could be found for the emergence of primitive precursors of strategic action. For these reasons, Wellman abandoned the traditional free recall task in favor of such problems as memory for future activities, preparation for future retrieval demands, and search strategies (Wellman, 1977; Wellman & Somerville, in press).

A nice example of this approach is a study by Wellman, Ritter and Flavell (1975). Two- and three-year-old children were shown a toy dog that was subsequently hidden under one of a set of containers. The experimenter left the room and asked the child either to wait with the dog or to remember where the dog was hidden. Their behavior in the experimenter's absence was observed via a one-way mirror. It proved difficult to obtain data from the two-year-olds who preferred not to wait around in the experimenter's absence! The three-year-olds in the memory condition, however, displayed a variety of delightful strategies, such as looking fixedly at the hiding place, retrieval practice (such as looking at the target container and nodding yes, looking at the non-target containers and nodding no), and baiting the correct container (by resting their hand on it, by moving it to a salient position, etc.). Children who demonstrated some activity in anticipation of future recall did remember better.

Wellman and his colleagues have also studied logical search strategies in young children. An object might be lost in a particular location in their playground and the children's attempts to retrace their steps in a logical fashion measured. For example, in a study by Wellman, Somerville and Haake (1979), a search was conducted for a camera lost in one of eight locations on a playground. The child's picture was taken by the to-be-lost camera at locations 1, 2 and 3. Evidence of logical search would be the child's initial search directed to location 3 as the site of the last place the camera had been used. From age 3 1/2 upwards, the evidence for such logical search is quite compelling.

Some recent work by DeLoache and Brown (1979: 1981a,b) combines the location search method of Wellman, Ritter and Flavell (1975) and the large scale environmental quality of the Wellman, Somerville, and Haake (1979) study. Using an overlearned hide-and-seek game, they found evidence of planful preparation for memory tests in children as young as 18 months of age. In a series of six studies the children were required to find a toy hidden in a location in a large scale environment (e.g., behind a chair, under a pillow, etc.). The main difficultly in these tasks was finding conditions that produced less than ceiling performance! We will discuss only one of these studies here, because of the somewhat unusual pattern of results. Children between 18 and 23 months of age were divided into two groups; one group played the hide-and-seek game in the laboratory, the other in the home. During the delay interval the child's activities were videotaped. Evidence of planning for future retrieval included (1) verbalizing about the toy or its hiding place, (2) looking toward the hiding place, (3) pointing at the hiding location, (4) approaching the

hiding location (the child walked toward and hovered around the correct location), (5) peeking at the hidden toy, and (6) attempting to retrieve the toy (reaching for it, an attempt that was foiled by the experimenter).

The proportion of overt indices of planning was twice as high in the laboratory than in the home. This might at first seem surprising (it was replicated twice), as it is generally assumed that familiar settings afford a suitable environment for the display of any strategic propensities that young children might be harboring. But consider one factor, accuracy. In both conditions, the children's performance was extremely high (85% or above correct). We argue that it is only in the unfamiliar setting that planning is necessary. Faced with the more demanding task of locating a hidden object in an unusual location, even children under two will show some overt signs that they plan for their anticipated retrieval attempts (DeLoache & Brown, 1981a).

The early emergence of learning strategies is an area wide open for future research. For example, we need to understand more about the conditions under which primitive precursors of memory strategies occur, the stability with which they are used by the same child across different settings, the similarities and differences between earlier and later forms of the activity, etc. Similarly, we know little about the influence of knowledge based factors; and the terms "familiar setting", "ecological validity", etc. need a great deal of "unpacking." But, the initial work on these topics is both exciting and illuminating.

3. Late Development of Strategies. The majority of work concerned with the development of strategies has focused on activities that enhance rote recall of words or pictures, but these are not the only form

of learning; indeed, in the high school years, although list learning is still a common activity, the emphasis shifts to strategies for coping with much richer semantic domains. And learning shifts to texts; students must not only perfect their reading but they must learn how to learn from reading (Brown, 1981, in press a). A great deal of the adolescent's school life is devoted to learning content areas from text and developing skills of scientific reasoning. The student must develop strategies for dealing with materials that are principled, organized and coherent.

In this section, we will consider examples of the strategies students develop to enable them to handle such situations. We would like to point out, however, that although the strategies have changed, the developmental methodology and theory that guided the investigation of "simple" rote recall activities has also been influential in guiding the investigations of more complex activities. In many senses, the qualitative developmental pattern found between grades 6 and 12 on reading and writing tasks is very similar to that found between grades 1 and 6 on simple rote recall tasks. First there is the early sporadic emergence of an appropriate activity, followed by increasing stability and transituational application with repeated use. These activities gradually become systematized and consolidated into a robust, reliable pattern of attacking reading and writing tasks. Production deficiencies and inefficiencies (Flavell, 1970a) occur along the way and these are related to performance decrements exactly as they are in young children undertaking simpler list learning tasks. Precocious maturity with the strategies leads to adult-like patterns and levels of performance. Mature learning is in large part the result of strategic application of rules and principles and the systematic

suppression of serviceable, but less mature, habits. And, even more striking in this domain, strategic activities cannot be understood in isolation from the other factors in the tetrahedron.

Literacy is the primary aim of schooling. Learning to read and write demands strategies that are appropriate to the "literacy domain," just as learning to remember demands strategies appropriate to the "remembering domain." In this section, we will examine some aspects of studying from texts, expository writing, and scientific reasoning, the three prime tasks of academic literacy.

a) Studying. There is a long history of interest in the types of knowledge and strategies students bring to the task of learning from texts -- notetaking, underlining, adjunct aids, question-asking, outlining, etc. (Anderson & Armbruster, in press; Brown, 1981, in press a). In the past, however, the work has been limited in several ways: first, the majority of prior work has concentrated almost exclusively on the study activity of adults, usually college students. Second, the majority of studies have been correlational rather than manipulative. And third, the most important limitation is that the majority of studies have shared a concentration on product rather than process. That is, the main focus has been on some outcome measure such as the test scores of students who do or do not use a certain strategy. Little or no consideration has been given to the activity of the studier, what she is actually doing while studying. An example of this is the large number of experiments that have considered the product (how well studiers do on tests), for example, of note-takers, but have ignored the processes that the note-taker employs; even the notes themselves are not examined for evidence of the process that the taker of notes might be using (Brown & Smiley, 1978).

In a series of studies with high school students, Brown and her colleagues have been investigating these common study strategies, using theories and methodologies adapted from developmental psychology. Of particular interest has been the relation between the activity spontaneously generated as an aid to learning and the performance levels achieved on a variety of retention and comprehension measures. A main focus has been on the influence of various forms of knowledge on the development and maintenance of a variety of selective attention (Brown, 1981, in press a) and effort-allocation (Wellman, in press) strategies.

As a preliminary to this program of research, Brown and Smiley (1977) estimated the ability of students from third to twelth grade to rate the units of complex texts for importance to the theme. Twelfth graders could reliably distinguish the four levels of importance that had been rated previously by college students. Seventh graders did not differentiate the two intermediate levels of importance, but they did assign their lowest scores to the least important and highest scores to the most important elements. Third graders made no reliable distinction between levels of importance in their ratings and even fifth graders could only distinguish the highest level of importance from all other levels.

These initial findings have important implications for studying. To go beyond retention of just a few main points, i.e., to achieve a more complete "fleshed-out" memory of the text, one must engage in active strategies to ensure increased attention to important material that will not be retained automatically. If young children have difficulty distinguishing what is important, they will also have difficulty studying. Quite simply, one cannot selectively attend to important material in the absence of a fine sensitivity to what <u>is</u> important (Brown, 1981).

As children mature they become better able to identify what are the essential organizing features and crucial elements of texts (Brown & Smiley, 1977). Thanks to this foreknowledge, they make better use of extended study time (Brown & Smiley, 1978). For example, when given an extra period for study the majority of younger students (fifth to seventh grade) appear to favor the strategy of passive, even desperate, rereading. But a certain proportion of students at all ages take notes or underline during study; the proportion increases with age. An analysis of the notes taken reveals a clear concentration on text segments previously rated as important.

The subsequent recall of the strategy users was superior to that of non-strategy users, and there was a clear relation of strategy use to increased efficiency after extra study time. Even fifth and seventh graders who spontaneously underlined or took notes showed an adult-like pattern and used extra study to differentially improve their recall of important elements. We would like to emphasize that efficiency of recall after extra study was not a function of age per se, but of efficient strategy use. Seventh graders who took effective notes recalled as well as college students. Eleventh graders who did not take suitable notes recalled like seventh graders. Similarly, in a summary-writing task, fifth and seventh graders who make adequate rough drafts before attempting a final version perform like college students (Brown, Day, & Jones, in press).

This sensitive relation between knowledge of textual importance, knowledge of suitable strategies, and estimation of one's current state of mastery, has been found in a series of school-like tasks, such as note-

taking, outlining, summary writing, and retrieval-cue selection (Brown, 1980, 1981; Brown & Day, in press; Brown & Smiley, 1978; Brown, Smiley, & Lawton, 1978). Here we will describe only one project in detail because it illustrates a pervasive problem we wish to emphasize, that is, students are often impeded in their development toward more mature study habits by the existence of a serviceable, well-used, inferior strategy that results in partial success.

Within the series of studies conducted by Brown and her colleagues, qualitative differences were repeatedly found in the type of notes, summaries and outlines produced by spontaneous users of a selective attention strategy. For example, the principal condensation rules used to summarize were found to be: deletion of trivia, deletion of redundancy, substitution of a superordinate term for a list of exemplars or a superordinate event for a list of subordinate episodes, selection of topic sentence if one were thoughtfully provided by the writer, or invention of a topic sentence if one were needed. To map the developmental progression associated with the use of the basic condensation rules, Brown and Day (in press) examined the ability of students from grades 5, 7, and 10 as well as various college students to use the rules while summarizing. Even the youngest children were able to use the two deletion rules with above 90% accuracy; but, on the more complex rules, developmental differences were apparent. Students became increasingly adept at using the topic sentence selection rules, with college students performing extremely well. However, the most difficult rule, invention, was rarely used by fifth graders, used on only a third of appropriate occasions by tenth graders and on only half the occasions when it was appropriate, even by college students. Of

interest is the fact that junior college students, a population suspected of having difficulty with critical reading and studying, performed like fifth graders on the summarization task (Brown & Day, in press). Experts (rhetoric teachers), however, used the selection and invention rules almost perfectly.

One explanation for the differential difficulty of the basic condensation rules is that they demand differing degrees of cognitive manipulation and they depart to a greater or lesser extent from the already existing strategy favored by the younger participants, the copy-delete strategy. Fifth graders tend to treat the task of summarizing as one of deciding whether to include or delete elements that actually occur in the surface structure of the original text. The strategy is as follows: (a) read text elements sequentially; (b) decide for each element whether to include or to delete; (c) if inclusion is the verdict, copy the unit more or less verbatim from text (Brown, Day, & Jones, in press). The same general strategy is employed by fifth and seventh grade notetakers (Brown & Smiley, 1978), and it is also applied to the task of outlining. Interviews conducted with seventh-eighth grade students concerning their study and research habits again suggest that this is a common method (Brown, 1981).

The simple copy-delete strategy is then used consistently in a variety of text processing tasks by 11-14 year old students, and it works relatively well, in that it gets the job done; it results in a product that is recognizably a summary, an outline, or a set of notes. It is because the simple copy-delete strategy is so generally applicable and meets with partial success that it is difficult to get students to attempt to use more complex rules. The fact that a student must replace a primitive strategy

that works adequately with a more sophisticated approach is often a difficult impediment to progress.

Experts' strategies are a radical departure from the copy-delete strategy. They systematically depart from both the surface wording and the temporal sequence of the text, combining across paragraphs, rearranging by topic cluster, and stating the gist in their own words. They rely heavily on the invention rule that demands a synopsis in their own words of the implicit meaning of the paragraph. The invention rule requires that the students add information rather than just delete, select or manipulate sentences. It is these processes that are the essence of good summarization, that are used with facility by experts and that are most difficult for novice learners (Brown & Day, in press; Brown, Day, & Jones, in press).

In summarizing the results of an extensive series of experiments on study skills, Brown (1981) emphasized four main points. The first three were (1) the gradual emergence of strategic planning; (2) the relationship between effective plans and efficiency; age per se is not the crucial variable; and (3) the close interdependence of strategic action and the remaining points in the tetrahedron. During the junior high and high school years, students develop and increasingly fine-tune a battery of serviceable skills for learning from texts. These include: underlining and taking notes on main ideas (Brown & Smiley, 1978), developing macrorules for comprehension, retention, and synopsis writing (Brown & Day, in press), outlining and mapping (Armbruster, 1979), self-questioning (André & Anderson, 1978; Brown, Palincsar, & Armbruster, in press; Palincsar & Brown, 1981), concentrating on previously missed or difficult

segments of text (Brown, Campione, & Barclay, 1979; Brown, Smiley, & Lawton, 1978), and the general propensity of treating studying as a purposive attention-directing and self-questioning act.

A fourth, more speculative point is that partially adequate strategies are often developed and that these impede progress toward the more efficient strategy. Once students have developed the inefficient strategy, they tend to apply it consistently in a variety of situations and maintain it for quite long periods of time. It is only with a great deal of practice that they abandon it in favor of the more mature strategy. Indeed many high school (and college) students never do. We will examine other examples of this phenomenon in the work of Scardamalia and Bereiter on writing and Kuhn on scientific reasoning.

b) Writing. Expository writing is the second major school activity that has recently received considerable attention from cognitive and instructional psychologists. As we do not have space to detail the natural history of the development of writing and revising skills, the reader is referred to excellent recent papers by Collins and Gentner (1980), Bereiter and Scardamalia (1980, in press), Scardamalia and Bereiter (1980, in press) and Nold (1980). Here we will concentrate primarily on the development of the partially adequate knowledge-telling strategy (Bereiter & Scardamalia, 1980).

Bereiter and Scardamalia describe the executive decisions demanded of children who are faced with a typical school writing problem. Thinking of what to write is a very difficult problem for the young student, both at the beginning of the task and throughout. For example, Keeney (1975) found that children who ceased writing after producing less than 100 words

invariably reported that their problem was simply that they could not think of anything more to say. With a little prompting, however, it could readily be shown that such children had a great deal of potentially usable knowledge. Nondirective prompts, such as "another reason is" or "on the other hand" were sometimes all it took to get the writing process going again (Bereiter & Scardamalia, 1980). Planning problems in writing are apparent even when the child is writing about a domain of which she has considerable knowledge.

A typical composition of primary grade children will consist of the form, I think X because of Y. The child might then give another reason for X or (rarely) explicate the link between X and Y. Usually at this junction the child will indicate that there is nothing left to say. The second common tactic that young children employ to extend their texts is to introduce a new theme based on Y. For example, when writing an essay on winter, the child might begin with "I think winter is the best time of year because you can make snowmen;" the child will then proceed for many more sentences telling all she knows about snowmen. Having exhausted that topic, the child will declare that the composition is ended, seemingly having "forgotten" the original purpose of the essay (Bereiter & Scardamalia, 1980). This general ploy is referred to as the knowledge-telling strategy (Bereiter & Scardamalia, in press).

A prototypical example of the knowledge-telling strategy is that adopted by many college students. In an essay examination, there is a question that cannot be answered. Instead of leaving the question blank, the student writes down everything she knows about that topic, even though the product in no way constitutes an adequate answer to the specific

question. College students resort to knowledge-telling in times of desperation. However, knowledge-telling is the dominant mode of the young writer who, using key words to set the process in motion, tells all she knows about a domain without tailoring or fine-tuning the output in response to the actual question. Flower (1979) has referred to this approach, charitably, as writer-based prose, i.e., prose dominated by the writer's memory of the domain, rather than the reader's needs.

The knowledge-telling strategy is a device favored by many novice, and not so novice, writers. And it bears many similarities to the copy-delete strategy used by students of the same age in note-taking, outlining and summary writing task (Brown, in press c). Like the copy-delete strategy, the knowledge-telling strategy is difficult to eradicate because it gets the job done. Copy-delete produces a product that is recognizably a summary, an outline, or a set of notes; and teachers will accept the product as adequate. Knowledge-telling also results in a recognizable product acceptable to teachers. Writing gets done on the topic in question.

Flower and Hayes (1980), considering talk-aloud protocols during writing, have noted the absence of advanced planning strategies in knowledge-telling subjects. Elaboration, restatement, and revision of the goals and subgoals of the assignment are repeatedly stated by experts. Knowledge-telling, writer-based novices do not often indulge in these refinements.

Reader-based, expert writers have reasonable criteria for terminating their writing task. The job is done, the goal is reached, the question is answered. How then do knowledge-telling writers exit the arena?

Termination rules for them include more mundane criteria such as "the end of the page," "I have three paragraphs and an essay must have three paragraphs," and so on.

The knowledge-telling strategy is distinguished by (1) a lack of goal-related planning; (2) a lack of internal constraints in the text, one sentence being as deletable as any other; (3) a lack of interconnectedness in the written output; (4) reliance on purely forward-acting serial production rather than recursive forward-backward revision processes; and finally (5) a remarkable lack of anything other than merely cosmetic revision (Nold, 1980).

The knowledge-telling strategy gives way to reader-based, responsive, mature writing only with great difficulty. It is an inefficient strategy that is retained because it meets with at least partial success. Like most production inefficiencies (Flavell, 1970), it lies halfway between the younger child's failure to find any content for writing, and the mature strategy of tailoring the output to the goal via executive strategies of goal-directed actions. It shares with the copy-delete strategy (Brown, 1981) its resistence to change because it results in a product that in many cases is acceptable; and it shares with copy-delete the problem that it impedes the development of high level activities. Fortunately, it also shares with copy-delete the fact that training can be introduced to overcome this obstacle to effective performance (Brown, Campione, & Day, 1981;, Day, 1980). For example, Scardamalia and Bereiter (in press) describe a variety of training devices for helping children develop (1) search and selection strategies prior to writing and (2) on-line processes needed to revise, evaluate and correct written output. The primary aim of

these procedures is to get children to concentrate on the higher level nodes in their discourse structure and prevent them from "downsliding" (Collins & Gentner, 1980) to details or lists of possible entries under a node. They aim to keep the child focused on the task, for example, of writing about winter and discourage downsliding to all the information in the node snowman. The child learns to forego knowledge-telling terminated by arbitrary exit rules and to develop reader-based, topic-responsive, mature expository writing.

c). Scientific Reasoning. High schools demand of their successful clients not only increased sophistication in literacy skills but also the development of formal operational skills of mathematic and scientific reasoning. Space limitations are such that we cannot deal with this topic in any reasonable detail (see Siegler, companion volume). Instead, we will describe one program that again illustrates the difficulty learners have in abandoning an existing strategy that results in partial success.

Kuhn and Phelps (in press) examined the development of scientific reasoning in the combination of elements task introduced by Inhelder and Piaget (1958). Their approach was to select fourth and fifth grade students who are (or should be) at a transition point for the skill in question and to examine their increasing sophistication with the task over a period of three months. By adopting a microgentic approach (Werner, 1961), they hoped to study the "process of development directly." Typical of Piagetian learning situations, the only feedback the students received was that generated by their own actions on the physical material (Inhelder, Sinclair, & Bovet, 1974; Karmiloff-Smith & Inhelder, 1974/75; Piaget, 1976; see Section IV.B.3).

The problem requires that the students determine which chemical of three present in a demonstration mixture is responsible for producing a chemical reaction (simplest problem); students must systematically isolate elements in such a way that they are able to determine unambiguously which of the potential elements is causally related to the outcome of chemical change. The "mature" strategy is to test in isolation each element in the outcome producing combination in order to assess its individual effect. Subjects were judged to have solved the initial problem if they specified the single effective element and excluded all other elements; they then moved on to more complex problems where two elements, and then three, were combined to produce the effect.

We will give only the flavor of the results. The most striking feature was the variability in the strategies a subject applied to the problem both within and across sessions. Far from a smooth gradual progression in expertise, the students, at least in the initial sessions, were very "patchy" in their strategy use. Students' "insight" into the problem shown in early sessions did not necessarily carry over to later sessions. Although many of the advanced strategies appeared in the intital sessions, stabilization and consolidation of this early competence was not achieved until quite late. Performance mastery was attributable to both this consolidation and systematization of advanced strategies (Karmiloff-Smith, 1979a) and a gradual, reluctant discarding of previously used, but less adequate, strategies. Kuhn and Phelps argue that it is the second of these processes, i.e., the freeing from the clutches of inadequate but attractive strategies, that was the most formidable impediment to learning.

The most attractive lure in the combination of elements task was the tendency to seek evidence that confirms rather than refutes a current hypothesis (Bartlett, 1958; Tschirgi, 1980; Wason & Johnson-Laird, 1972). The second inadequate but preferred strategy was that of false-inclusion, i.e., the tendency to infer that whatever occurs in conjunction with the outcome is causally related to that outcome. These two false strategies were difficult for subjects to relinquish on the easy problems, thereby impeding initial success; and they tended to recur among subjects who went on to the more advanced problems. We would like to argue that the confirmation-seeking and false-inclusion strategies share common features with the copy-delete and knowledge-telling strategies just reviewed. All are maintained because they do result in partial success and are recognizable attempts to get the job done. They are resistant to change because they are typical of everyday reasoning (Bartlett, 1958; Cole, Hood, & McDermott, 1978), where demands for the most efficient strategy are rarely stringent. The process of development is not just one of acquiring increasingly more refined and sophisticated strategies; development involves the systematic consolidation, and growing conviction of the appropriateness, of the mature strategies, combined with the rejection of plausible but less efficient habits.

4. Strategy Development Revisited. In summary, we are beginning to map out the development of strategies for learning over a greatly increased age range and over a greater diversity of tasks than was the case in the late sixties and early seventies. Strategic activities can be observed at very young ages if the observer knows what to look for. In contrast, faced with the academic task of writing, studying texts, or

scientific reasoning problems, much older learners are surprisingly sporadic in their strategic intervention. But, we would argue that the development of complex strategies demanded by advanced academic tasks traces a route that is similar in kind to that followed during the acquisition of list learning routines. Rather than being a question of presence or absence, development involves the systematic organization and refinement of effective routines at the expense of ineffective activities. Major impediments to progress are attractive intermediate strategies that meet with partial success and are consistent with the type of reasoning that dominates everyday cognition (Bartlett, 1958).

We argued that for any strategic activity one must distinguish between the early fragile state and its later robust quality (Flavell & Wohlwill, 1969). Although it is possible to find primitive precursors at a very young age, the activity is fragile and can easily disappear. The activity is also tightly welded, or restricted, to limited domains of activity (Brown, 1974, 1982; Fischer, 1980; Fodor, 1972; Rozin, 1976). The fact that the child thinks to prepare for retrieval in a toy hiding game does not necessarily mean that she will select a suitable cue to bait the correct container in a very similar retrieval cue selection task. The appearance of strategies is patchy, the propensity to be strategic has not become so ingrained that the child will routinely search for ways to be strategic.

Although we have ample evidence from the early memory literature that stripping away unessential demands and/or situating the experiment in the familiar are procedures that result in surprising competence in preschool children, we would not like to give the impression that it is only the

nature of laboratory tasks that has led us to underestimate the cognitive maturity of the preschooler (Flavell, 1982). It is just as important to note that two-year-olds show fleeting glimpses of their capabilities only under circumstances where considerable ingenuity has been expended in selecting a suitable setting. And, even then, young children's learning and problem solving strategies are unreliable. Sometimes they do show signs of knowing a great deal more than was previously supposed. But more often they do not. In the current trend to prove the early emergence of almost any cognitive capacity, we should not overlook the obvious fact that six- and seven-year-olds are able to show their understanding in a wider range of situations, including the much maligned laboratory task. The cognitive competence of the grade school child is far more robust; it is manifested on many criterial tasks. This compares sharply with the fragile nature of the preschooler's fleeting moments of insight. We would like to argue (Gelman & Baillargéon, this volume; Karmiloff-Smith, 1979a; Piaget & Inhelder, 1973; Thornton, in press; see also Section IV) that early competence tends to be rather tenuous, consisting of a set of juxtaposed procedures that have not been organized into a systemic, coherent body of knowledge.

It is the coherence, sturdiness, and resistance to countersuggestions that sets the older child apart from the very young learner. The propensity to be strategic on a variety of learning tasks is much greater, and a considerable degree of ingenuity is often needed on the part of the experimenter to prevent the older child from being strategic. The mature form of the strategy differs from the earlier forms not only in terms of its stability, but also in terms of its relatively transituational quality.

For example, the young child's use of a primitive rehearsal strategy is unreliable; she fails to refine it to conform with changing task demands and she often fails to use it in a variety of situations where it would be applicable. Strategy use in mature users is characterized by its robust nature, its internal coherence, and its transituational applicability. There are, of course, limits to this transituational flexiblity. Everyone's knowledge is context-bound to a certain degree (Brown, 1982) and this is true of strategy utilization. We will return to this point later (Section V).

Our final point on strategies is that we cannot emphasize enough the importance of other factors in the tetrahedron for determining the form and function of strategic intervention. Strategies and knowledge factors are intimately related. Even the prototypic "knowledge-free" strategy of rehearsal (one can perfectly well rehearse meaningless material) is influenced by the nature of the material to be rehearsed and the knowledge that the subject has concerning the potential organization of that material (Ornstein & Naus, 1978). The nature of the criterial task is again a crucial factor in determining whether a strategy will be used. Adults do not rehearse when the list is either too long or too short, or when another strategy can be applied with less effort. And young children are only spontaneously strategic in circumstances where the criterial task represents a goal that they understand (e.g., finding a toy); remembering for remembering's sake is not a situation that will reveal young children's propensity to make active attempts to learn. Strategic action must be evaluated as one part of the tetrahedron, influenced by the subjects' knowledge and capacities, the nature of the materials to be learned, and the end point of learning, the criterial task.

B. Characteristics of the Learner

We turn now to the general question of what it is that the learner brings to the learning situation. This is no small topic! The characteristics of the learner include, of course, the previously described repertoire of strategic skills that the learner may or may not access when planning her learning activities. Some of the many other factors that can be considered under this heading are those general "catch-all" categories of knowledge, variously referred to as "knowledge-of-the-world," "the knowledge base," "memory in the broad sense," "schematic knowledge," etc. (Brown, 1975). Further, there is the popular topic of metacognition (Flavell & Wellman, 1977); one characteristic of the learner is, indeed, the declarative knowledge that she has concerning her own knowledge, be it factual or strategic. And finally, a major characteristic of the learner that continues to be controversial is her "capacity."

In this section we will consider only (a) some recent work reaffirming the importance of subjects' factual knowledge in determining their learning activities and efficiencies and (b) the topic of capacity limitations affecting efficiency of learning. Both topics will be treated primarily as illustrative of the necessity to consider the learners' characteristics when viewing the interactions of the tetrahedron. We will defer to a separate section our discussion of metacognition (see Section IV and V).

1. Factual Knowledge. The obvious fact that what a person currently knows must influence what she can learn has received considerable attention in recent years. Developmental psychologists must be concerned with issues of differential knowledge, because age and knowledge are usually highly correlated. There has been, however, a tendency to act as if the prime

consideration was to control or equate for knowledge factors. Developmental variations in knowledge are often regarded as a source of extraneous variability. For example, in standard memory tasks an attempt is made to insure that even the youngest subjects are familiar with the stimuli, at least to the level that they can name them. If a name is not readily given by a small participant, the experimenter generously provides one and then operates as if stimulus familiarity were equated across ages. That familiarity may involve more than access, or even speed of access, to the name code was rarely considered in early studies of memory development. Variations in performance across ages were attributed to factors other than variations in knowledge, e.g., capacity limitations or strategy deficits (Chi, 1976).

Perhaps a more enlightened way that developmental psychologists have expressed concern with differential knowledge has been in their treatment of instruction. If one wishes to instruct a child to perform in a way she previously could not, the most intelligent way to proceed is to uncover her starting level of competence. It is a widespread assumption of developmental psychologists of quite divergent theoretical viewpoints that the distance between the child's existing knowledge and the new information she must acquire is a critical determinant of how successful training will be (Inhelder, Sinclair, & Bovet, 1974; Piaget, 1971; Siegler, 1981). Thus, it is a critical concern for those involved in instruction to detail the stages through which the learner must pass. The map between the child's current understanding and the instructional routine selected is a critical determinant of the success of that instruction.

Then there is the question of task difficulty. A task is easy or hard and material is comprehensible or not to the extent that it maps onto the preexisting knowledge and preferences of the learners. Little thinkers, who lack some basic knowledge, should be hindered in their comprehension and retention of any information that presupposes the existence of that prior knowledge. A good example would be studies that show a clear link between children's ability to free recall material and the compatibility of that material with their own knowledge (Denney & Ziobrowski, 1972; Perlmutter & Ricks, 1979; Naron, 1978; Stolz & Tiffany, 1972). This area of research is plagued with methodological difficulties (Murphy, Puff, & Campione, 1977), but there does seem to be support for the influence of stimulus familiarity on children's recall performance. For example, Richman, Nida, and Pittman (1976) used familiar words known to all their subjects; but the children's judgment of their meaningfulness varied as a function of age. When common lists were used, the older children outperformed the younger ones; but when the lists were tailored to the child by equating them for meaningfulness in an age-appropriate manner, no age differences were reported. Similarly, Lindberg (1980) used standard taxonomic lists vs. lists made up of categories relevant to the children's lives (i.e., names of school teachers, television shows, books in their reading curriculum, etc.). Again, the age difference disappeared on the familiar materials, thus providing strong positive evidence of the effects of knowledge on recall performance.

Another successful ploy is to show that experimentally induced preexisting knowledge determines what is understood and retained from passages. This has been successfully demonstrated with both children

(Brown, Smiley, Day, Townsend, & Lawton, 1977) and adults (Anderson & Pichert, 1978; Bransford, 1979; Chiesi, Spilich, & Voss, 1979); even young children disambiguated vague or misleading sections of text in a manner congruent with their preexisting expectations (Stein & Trabasso, in press). Indeed, it is not necessary in a standard prose-recall situation to manipulate age as well as preexisting knowledge. Inducing adults to take different perspectives before reading a passage is an ideal way of demonstrating that comprehension is an interaction of expectations and actual textual materials (Anderson & Pichert, 1978; Bower, Black, & Turnure, 1979; Bransford, 1979).

Recent work by Chi has shown an intriguing inverse finding that is just as pertinent to our argument. Chi has been investigating the memory and metamemory performance of skilled chess players, an honorable psychological pursuit dating back at least to Binet (1894). Chi's twist is that in her sample of players knowledge is negatively correlated with age; the children are the experts whereas the adults are the novices. It is the experts who outperform the novices both in terms of actual memory performance and in predicting in advance how well they will perform.

Let us consider another of Chi's studies in detail, the dinosaur expert (Chi & Koeske, in press). Chi's subject was a 4 1/2-year-old boy who knew more than anyone need know about dinosaurs. The child was asked to generate the names of all the dinosaurs he knew. In seven sessions the child generated 46 dinosaurs of which 20 were selected to be the better-known and 20 the lesser-known set. Assignment to set was based on frequency of generation (4.5 vs. 1) and the frequency with which the dinosaurs occurred in the texts from which the child had been read.

Chi established both the properties the child could recognize and generate in a clue game in which the experimenter and the child took turns generating properties which the other had to identify. Using the properties and frequency data, a network representation was mapped with directional links between nodes representing generation or recognition. The number of links between nodes indicated the frequency of mention. The links fell into seven main types: habitat, locomotion, appearance, size, diet, defense mechanism (e.g., spines), and nickname. On the basis of these mappings, Chi could identify what knowing more means; knowing more is identified with the number of property nodes associated with each concept node, the number of interrelations among the nodes, and the frequency with which each dinosaur node shows a particular property node. The better-known set differed from the lesser-known set quite dramatically in terms of the complexity, density and interrelatedness of the representation. Although it may not be possible to "equate" for knowledge in psychological experiments, Chi's elegant study does point to ways of mapping a child's representation and of quantifying what it means to know more.

Having mapped the knowledge base concerning well-known and not-so-well-known dinosaurs, Chi looked at the child's free recall of the two sets. The lists were read to the child and he was required to recall them three times. The number of items recalled across trials for the better-known dinosaurs it was 10, 9 and 9, and for the lesser-known dinosaurs was 6, 5 and 4. The child's recall for the better-known set was twice as high as for the lesser-known set.

What is not clear in the dinosaur study is the significance of the findings vis-á-vis the strategies and knowledge interrelationship. The

free recall task is a difficult vehicle for studying the interaction of strategies and knowledge. Improved recall over trials, and even clustering, occur in adults and children exposed to taxonomic lists that they are not set to learn deliberately, i.e., under incidental learning situations (Murphy & Brown, 1975; Ritchey, 1980). Chi would like to argue, as does Lange (1978), that improvement in both the quality and quantity of recall across ages is not solely the result of strategic intervention, as has often been claimed, but is more the result of the corresponding growth in knowledge as a function of age. Hence, she concludes that "the elaborateness and richness of the representation of the concepts in memory determines the quantity and quality of recall" (Chi & Koeske, in press).

We would argue that although Chi has positive evidence for the importance of knowledge factors, she has only indirect evidence concerning strategic factors. And further, we would argue that the critical experiment, although technically difficult, is feasible and has not yet been undertaken.

Consider the recall trials data. Chi's dinosaur aficionado "recalled" 10 of the 20 well-known animals and five of the less well-known. Performance, if anything, dropped over the three trials. If the learner were using an organizational strategy to guide recall, one would expect him to improve over trials; indeed, in developmental work it is essential to give multiple trials for evidence of strategy use to show up (Murphy, Puff, & Campione, 1977). Chi's learner did not show this prototypical improvement over trials, thus providing some indirect evidence that strategies for learning were not employed. But Chi's expert was four years old.

Consider a fictitious eight-year-old dinosaur expert who has at her command not only an organized knowledge base but also a serviceable repertoire of memory strategies. We presume that this learner would show a superiority based on knowledge factors, i.e., she would recall more from her familiar than from her unfamiliar set. But, in addition, she would be able to employ deliberate strategies to help her improve over trials on both sets. If the task were modified somewhat, so that the dinosaurs were presented on cards (pictures), one might gain additional evidence of strategic activity such as sorting into categories (habitat, locomotion, etc.) in the service of memorizing. Sorting should be easier and more stable for the familiar than less familiar sets; if so, one might predict greater improvement over trials for the better known set. Relationships between input and output organization might also provide additional evidence of the interrelation of strategies and knowledge.

Persistent controversy in the memory development literature has surrounded this issue of inferring something about the nature of the representation of knowledge (semantic memory) on the basis of performance in memory tasks. One controversial instantiation of this problem was the concern with putative improvements over time in "memory" for logical organizations (Liben, 1977; Piaget & Inhelder, 1973). A less esoteric version of the problem is the routine attribution of knowledge structures only to those who "use them" in the common free recall task. Furthermore, there is no reason to suppose that the presence of organized recall necessarily implicates the use of deliberate strategies. Lange (1978) has pointed out that clustering may very well be the more-or-less automatic result of strong interitem associations in the knowledge base. Lange's

argument is one of semantic capture; that is, the compatibility between the organization of the material and the organization in the head is such that willy-nilly output is organized. Unfortunately, it is difficult to distinguish between effects that are due to "automatic" semantic capture and the use of deliberate organization strategies in free recall tasks (Mandler, this volume).

Tasks other than free recall that tap the child's organizational structure provide a different picture of the child's knowledge base. For example, in a semantic priming task (Sperber, McCauley, Ragin, & Weil, 1979), the speed of identifying the second word of a pair is greater if the two words are drawn from the same, as opposed to different, categories. The latency to identify "cat" is faster if the previous word was "horse" than if it had been "house." On such tasks, very young and quite severely impaired learners appear to be sensitive to the taxonomic structure of the lists. Comparable data can be gleaned from developmental studies of release from proactive inhibition (Kail & Siegel, 1977).

We would like to argue that the nature of the criterion task is in large part responsible for the attribution of a certain kind of knowledge to a certain kind of knower. At least this is true in the current literature. We should also be wary about leaping to conclusions about knowledge factors without systematically examining the nature of both the materials and the criterion task. Consider the following study by Smiley and Brown (1979). Children from kindergarten, first and fifth grade, college students and elderly adults were given a picture-matching task and asked to indicate which two items of three were alike. The items could be paired taxonomically or thematically, i.e., a horse could be paired either

with a saddle (thematic grouping) or a cow (taxonomic grouping); a needle with a pin (taxonomic) or a thread (thematic). Younger (kindergarten and first grade) and older (CA = 80) subjects reliably chose the thematic grouping whereas the "schooled" samples (fifth graders and college students) chose the taxonomic grouping. But consider a slight change in the criterial task. After the students had made and justified their original choice, they were asked if there were any way that the alternate pairing could be justified; the subjects were perfectly happy to give the alternative explanation. Choice of thematic or taxonomic organization reflected preference rather than a fundamental change in underlying organization. This preference affected both learning rate (Smiley & Brown, 1979) and memory performance (Overcast, Murphy, Smiley, & Brown, 1975).

Whereas there is little evidence as yet to suggest that there are fundamental qualitative differences in the nature of representation as a function of age (see Mandler, this volume, for a detailed discussion), there are differences in preference for various organizational formulas, and differences in the facility with which experts and novices can gain access to the organization that they have. For example, the young child's taxonomic knowledge may be revealed in "passive" situations like the semantic priming task, but this does not mean that she can access that organization to form the basis of a systematic sort, or even more demanding, harness that organization to design a strategy in the service of deliberate remembering. If we use only the most demanding task, we will have a pessimistic picture of what the child knows. The nature of the criterial task must be scrupulously examined before we make inferences concerning the organization of knowledge or the child's propensity to be strategic.

2. Dynamic vs. Static Conceptions of Knowledge. It is not uncommon for theorists to attempt to explain performance differences between young and old, good and poor, expert and novice learners in terms of the adequacy of their factual knowledge base. The group that performs well does so because it has already acquired the background knowledge necessary to perform the task, whereas the less successful group lacks this knowledge. These claims are undoubtedly true, but perhaps of greater interest to a developmental psychologist is how these differences in knowledge came about and how these differences affect strategy utilization, etc.

Issues concerning the importance of content knowledge can be approached from two different perspectives that are complementary rather than mutually exclusive. From a static perspective, the major question is, "How does the current state of one's knowledge affect performance?" The major question from the alternate perspective, the dynamic perspective, is "How did one's knowledge base get to be the way it is, and how does it change?"

Many of the traditional theories borrowed from the adult, cognitive literature reflect the static perspective. Theories of frames, scripts and schemata represent a case in point. From the perspective of these theories, it seems clear that lack of relevant knowledge "causes" many problems such as the inability to learn or remember new sets of information. The dynamic perspective suggests a different approach to this issue: lack of relevant content knowledge can be viewed as a symptom, as well as a cause. Thus, a theorist can assume that the knowledge base is one major determinant of current performance (a static perspective) yet still believe that "something else" accounts for, or at least contributes

to, differences in the development of the knowledge base (a dynamic perspective). We argue here that the something else is access; people differ in the degree to which they spontaneously utilize potentially available information in order to understand and learn.

Imagine a prototypical developmental study. One group of children (the older, more experienced, etc.) performs better than the other. But, for the sake of argument, make the additional assumption that both groups possess the content knowledge necessary for successful performance. In such cases the key factor is the degree to which people spontaneously access or utilize potentially available resources in order to understand and learn new information. For example, in a recent study by Bransford, Stein, Shelton and Owings (1981), academically successful and less successful fifth graders were asked to learn a passage about two kinds of robots. The first paragraph of the passage included a brief introduction and a description of the function of each robot. The extendible robot could extend itself to the height of a two-story house and was used to wash outside windows in two-story houses. The non-extendible robot was designed to wash outside windows in tall highrise apartment buildings. The remaining paragraphs described particular properties of each robot, properties that were potentially meaningful given the tasks that each robot had to perform. For example, the robot for highrise buildings had suction cup feet to help it climb; it was light and had a parachute in case it should fall. The robot for two-story buildings was made of heavy steel for stability and had spiked feet to stick into the ground, etc. The relevance of the various properties was not explicitly explained.

Academically successful students spontaneously used information about the function of each robot to understand the relevance of various properties. Their memory for the properties was excellent and the students were generally able to explain why each robot possessed its various properties. Another group of academically successful students received an explicit version of the robot passage in which the relevance of each property was explained in the text. The ability of these students to remember the properties and explain their significance was no better than that of students in the implicit group.

The academically less successful students exhibited a different pattern of performance. Those who received the implicit version had a difficult time recalling properties and explaining their significance. Performance for those receiving the explicit version was considerably better. It became clear that the less successful students who received the implicit version had the potential to understand the significance of the properties (or the vast majority of the properties, at least), but they failed to ask themselves how previously available information about the functions of each robot might make each fact more relevant or significant. The less successful students did not spontaneously activate knowledge that could clarify the significance or relevance of the properties. They had the potential to do so but did not do this spontaneously; they had to be explicitly prompted to ask themselves relevant questions about the information they were trying to learn. These additional prompts were not required by the successful students who could provide them for themselves.

The tendency of some children to miss significant details that would alter their interpretation can have pervasive effects on their abilities to

learn from experience. For example, Bransford et al. (1981) asked their fifth graders to read a passage about camels; part of the passage emphasized problems such as surviving desert sandstorms, other parts discussed facts such as "Camels can close their nasal passages and have special eyelids to protect their eyes." Many of the academically less successful students failed to utilize information about the sandstorm to interpret the significance of facts about the camels' nasal passages and eyelids. However, successful students who did understand how various properties of camels help them survive desert sandstorms had a basis for understanding a new passage that described the clothing worn by desert people (e.g., these students could understand the significance of wearing veils or other forms of face protection). Hannigan, Shelton, Franks and Bransford (1980) have devised analogues of situations where particular events are or are not interpreted as instances of more general principles and have assessed the effects on students' abilities to deal with novel-but-related materials. Students who were prompted to interpret each acquisition event as an instance of more general principles exhibited a much greater ability to transfer to novel-but-related events (see Section V).

Bransford et al. (1981) have discussed several studies designed to explore how children approach the problem of learning new information. The children in these studies had the background knowledge necessary to learn the information, but some of them consistently failed to access this knowledge; they failed to ask themselves how potentially available information could clarify the significance or relevance of new factual content. The failure to perform these activities could affect the

development of an adequate knowledge base and hence jeopardize the chance to learn subsequent related information. Repeated superficial processing of this type would lead to a cumulative deficit, or a knowledge base impoverished over a wide range of factual topics. Inadequacies in the development of the knowledge base are not only causes of various problems but may be symptoms as well.

Of course, the performance of less successful learners can be improved by explicitly prompting them to use appropriate strategies or to activate relevant knowledge. This prompting may take the form of "leading questions," or it may involve direct instruction. One problem with this approach to directed learning or teaching is that a teacher or writer cannot always anticipate what each learner needs to know in order to understand a message. An even greater problem is that this approach may indeed help people better understand and remember particular sets of materials, but it does not necessarily help them how to structure their own learning activities. The development of the ability to learn on one's own is the learning to learn problem (Bransford et al., 1980; Brown, in press a). To function efficiently as an independent learner, the child must be able to access her available knowledge and apply it appropriately. Students vary not only in what they know but also in what they do with what they know. Knowledge is necessary but not sufficient for performance, for it is the efficiency with which a learner uses whatever is available that defines intelligence (Brown & Campione, 1981, in press; Campione, Brown, & Ferrara, in press; see also Section V).

3. Capacity. A continuing controversy in the literature surrounds our second characteristic of the learner, i.e., her working memory, or

attentional capacity. This is, indeed, an important feature of the learner. Few would doubt that novices and young children are hampered in their efforts to learn by a limit on what they can hold concurrently in memory. And convincing arguments have been put forward that overloading a child's working capacity is an important factor that leads to immature behavior on a variety of tasks. For our purposes here, we will concentrate on the central idea that one cannot talk about capacity differences without considering all four factors of the tetrahedron.

It has been amply demonstrated that the functional capacity of the human information processing system increases developmentally (e.g, Dempster, 1978; Huttenlocher & Burke, 1976). However, whether this reflects changes in capacity per se, or in the efficient use of that capacity is a debatable issue. The resolution of this controversy has been hampered by the complexity of an essentially interactive system. The answer is not going to be a simple "it's all knowledge," "it's all strategies," "it's amount of space," "it's durability," etc. Concomitant to the observed increase in "capacity" with age, other characteristics of the child, e.g., the complexity of her knowledge base and her repertoire of learning activities, are also developing and the rate at which these factors are changing varies widely both within and between individuals. Moreover, the interdependencies existing between these factors have not been completely specified. This greatly complicates the task of constructing a pure measure of capacity that can be applied to people of different ages. We will elaborate upon this problem in the following discussion of the developmental data. Research suggesting that changes in (a) mental space, (b) basic processing operations, (c) the knowledge base,

and (d) strategy use underlie observed changes in functional capacity will now be considered.

Mental Space and Capacity. Pascual-Leone (1970) hypothesized that the Piagetian stages of cognitive development are determined primarily by the growth in capacity of a central computing space, a construct that he terms M space. M space is equivalent to the number of schemes or discrete units of information that can be operated upon simultaneously. This quantitative construct is assumed to develop as a linear function of age (i.e., from 1 unit at age 3 to 7 units at age 15). To test this hypothesis, Pascual-Leone (1970) constructed the "compound-stimuli visual information" task. His subjects (ages 5, 7, 9 and 11) first learned a different response (e.g., clap hands, open mouth) to each of a number of positive instances of a variety of visual stimulus dimensions (e.g., red color, large size). The children were then presented with compound visual stimuli that were to be "decoded" by responding appropriately to each of the cues present in the stimuli. According to Pascual-Leone, the number of correct responses a child emitted in this task corresponded to the maximum number of schemes that she could integrate without exceeding her available information processing capacity. In support of the model, Pascual-Leone found that performance increased as a function of age; he concluded that these developmental increments were primarily due to increased M space. Corroborating evidence has been obtained within other domains by Case (e.g., 1972, 1974).

Pascual-Leone's (1970) model and his tests of that model have been criticized on a number of grounds including procedural, statistical and metatheoretical ones; but by far the most damaging criticisms concern the

confounding of M demands with demands on certain basic processes, on strategies, and on executive control (Rohwer & Dempster, 1977· Trabasso & Foellinger, 1978; Trabasso, 1978; for a reply to these criticisms. see Pascual-Leone, 1978; Pascual-Leone & Sparkman, 1980). Case (1974, p. 382) asserts that "according to Pascual-Leone's neo-Piagetian theory of development, a subject's performance on any given cognitive task is a function of three parameters: the mental strategy with which she approaches the task, the demand which the strategy puts on her mental capacity (its M-demand), and the mental capacity which she has available (her M- space)." Thus, in order to infer a difference in M space between two children of different ages, it is necessary at minimum to insure that they are using the same strategy that places an equivalent drain on mental capacity in each case. The tasks used by Pascual-Leone (1970) and Case (1972, 1974) are obviously facilitated by certain skills and strategies (e.g., analysis of complex stimuli and ordering skills) that undergo development during the age range of interest.

Basic Processing Operations and Capicity: More recently, Case and his colleagues (Case, Kurland, & Goldberg, in press) have suggested that a person's total processing space is composed of space available for storing information and space available for executing cognitive operations. Although total processing space is assumed to remain constant as one develops, its two components are believed to fluctuate with a trade-off existing between them. Thus, Case et al. propose that the improved functional capacity that accompanies development reflects increases in storage space, which accompany the decreasing amounts of operating space necessary for performance. The decrements in necessary operating space

occur as a result of the growing speed, efficiency, and automaticity of basic processes (e.g., encoding and retrieval).

Case et al. reported a series of studies supporting their model. In the first study, they demonstrated that between the ages of three and six, word span (i.e., roughly the maximum number of words that a person could repeat in any order) was linearly related to the speed of repeating individual words. In a second study, word familiarity was manipulated (i.e., adults were given nonsense words) in order to equate adults and six-year-olds on their speed of word repetition. This manipulation resulted in the disappearance of age-related differences in word span. The amount of space the adults required for basic operations increased in the case of nonsense words, with a concomitant decrease in the amount of available storage space in short-term memory.

Similar results were reported in a third study in which a counting span task was administered to children from kindergarten through sixth grade. This test required the children to count each of a number of arrays and subsequently to recall the number of dots in each of those arrays. A linear relationship was found between developmental increments in counting span and developmental increments in counting speed. Furthermore, in a fourth study, by requiring adults to count in an artificial language, both the speed of counting and the counting span of adults were reduced to a first grade level. Case et al. concluded that there is no developmental increase in total processing space, but rather that reductions in the necessary operating space are responsible for the developmental increments in span. They acknowledge, however, that this conclusion rests upon the validity of their operational definitions of the amount of required

operating space. The source(s) of any increases in operational efficiency (e.g., maturation, experience) and the mechanisms by which such changes might increase memory span (e.g., less "attentional interference," more time for rehearsal or other strategies) are also issues which remain to be addressed.

Huttenlocher and Burke (1976) arrived at a similar conclusion. They obtained measures of digit span from four-, seven-, nine- and eleven-year-olds. Their experimental manipulation was to vary the sound pattern (melody, prosody or monotone) and the temporal groupings. The effects of sound pattern were quite small and not clearly related to age. Temporal grouping, however, improved the spans of all age groups to roughly the same extent, suggesting that differences in subject-imposed organization cannot be responsible for developmental differences in memory span. They conclude that the growth of memory span is probably not due to the development of active strategies and that, therefore, it probably results from improvements in basic processes, such as the identification of individual items and the encoding of order information. In a comprehensive review of the literature, Dempster (1981) came to a similar conclusion.

Knowledge Base and Capacity: It is possible that knowledge base restrictions may underlie the child's relatively poor memory span and perhaps her processing inefficiencies as well. Chi (1976) suggests that a young child can be restricted by her knowledge base in three different ways. First, the chunks of information that constitute her knowledge base may be smaller (Simon, 1972, 1974). Materials that are less familiar to a child than to an adult may correspond to more chunks of smaller size for the child. Second, the chunks in the child's knowledge base may be less

accessible in the sense of fewer associations between chunks in the network. Third, the child may simply lack chunks in her knowledge base for totally unfamiliar stimuli. Chi (1976) reviewed research demonstrating that materials supposedly varying in familiarity (i.e., digits, letters, concrete words and geometric figures) resulted in varying memory spans for adults, but not for children, and concluded that this is due to greater variations in the structure of the knowledge base for different types of material on the part of adults than of children.

Strategies and Capacity: It has been suggested throughout the cognitive literature that grouping and rehearsal are the two major strategies that provide advantages in tasks such as memory span, but there is not a great deal of evidence to support this position. Experimenter-imposed grouping does not eliminate age differences in span performance (Huttenlocher & Burke, 1976). On the contrary, such manipulations have sometimes accentuated age differences. For example, McCarver (1972) found that ten-year-olds and college students displayed greater probed short-term memory for pictures when spatial and temporal cues, as well as grouping instructions, were provided, but that six- and seven-year-olds did not improve under these conditions. Generally, however, grouping improves the performance of young and old alike (Baumeister, 1974; Harris & Burke, 1972; Huttenlocher & Burke, 1976).

We know of no positive research demonstrating active recoding of stimulus items in short-term memory tasks by young children and in general little investigation has been done in this area. Failure to recode might be due to at least a couple of different problems (Chi, 1976). First, a child may not know when and/or how to go about recoding. Second,

recognizable chunks appropriate for recoding might not yet exist in the knowledge base for many types of stimuli. In general, then, there is little evidence to suggest that developmental increases in memory span are due to the acquisition of grouping strategies, although the paucity of data should be noted. The same might be said for rehearsal strategies (see Frank & Rabinovitch, 1974; Huttenlocher & Burke, 1976, for a discussion of this issue).

We regard the capacity development issue as moot given current evidence. But we tentatively conclude that there is little evidence to suggest that total processing capacity per se changes at least after four years of age (there are no data on younger children). Instead, developmental increases in span are due to an interaction of three general factors that undergo changes during childhood. These factors are the structure of the knowledge base, the use of strategies, and the efficiency of basic processes. Which of these variables will be most responsible for differential performance across ages may depend upon such things as the constraints of the task, the type of materials, and the ages of the subjects.

We would also like to argue that many of the changes that underlie age-related increases in functional capacity may be similar to those that occur with the development of expertise in general. Furthermore, it remains to be seen to what extent the allocation of short-term memory capacity is automatic and to what extent it is a volitional process, requiring fairly sophisticated executive monitoring skills (Shiffrin & Schneider, 1977). Equally speculative at this stage is Chi's (1977) implication that the development of "metacognitive" skills may play a role in the increasing efficiency of capacity allocation with age.

Despite the flurry of recent activity in this area, we have little evidence to refute or substantiate Olson's (1973) characterization of capacity increments as follows:

> The changes we find are associated with the child's ability to recode or encode, to plan and monitor, to integrate and unitize. Broad limits on information processing capacity, which may be biological in origin, are relatively constant, but how the child operates within these limits undergoes systematic and profound development. (p. 153)

C. The Nature of the Materials

The third point of the tetrahedron concerns the nature of the materials. We will use only one example here of the importance of considering the materials to be learned, that is, the controversy surrounding developmental trends in recognition memory. However, an important theme throughout the chapter is the influence varying forms of materials have on the learning process (see Mandler, this volume, for a full treatment of this question).

1. Recognition Memory

One issue that concerned developmental psychologists during the early seventies was the existence of developmental effects in recognition memory. The original question that motivated the research was whether there existed some class of "memory" task that would place little demands on capacity limitations, and/or strategies, and/or knowledge factors and, therefore, would result in excellent performance in young subjects notorious for their poor memory performance. The argument was that it is uninteresting to point out that retarded children, for example, have poor memories. More informative would be studies showing areas of relative strength as well as areas of weakness (Brown, 1974; see also Wellman, 1977, for an extension of

this argument to young children). The initial studies in recognition memory did, to some extent, provide the needed data. Young children and retarded learners showed excellent recognition memory for particular kinds of stimulus materials; such children could readily identify previously seen distinct familiar pictures from a set including novel items (Brown & Scott, 1971). Children could even tolerate some quite similar distractor items such as the same character in a different pose (Brown & Campione, 1972), or two quite similar instances of the same conceptual category (Siegel, Kirasic, & Kilburg, 1973).

The original work with recognition memory was interpreted as an attempt to show that the process of recognition itself was developmentally insensitive, as if "recognition" were somehow identifiable in isolation. We would like to argue that this question is not well motivated, because it is impossible to consider the development of recognition memory without asking, "recognition of what?" A particular recognition memory task will be easy or hard depending on (1) the "nature of the materials," e.g., the similarity of the distractors along physical and/or conceptual dimensions; (2) the compatibility of the materials with the analyzing structures of the learner (knowledge base factors); and (3) the extent to which deliberate strategies can be used to enhance learning (learning activities). If the subsequent spate of recognition memory studies are analyzed in this light, the picture to emerge becomes quite cohesive.

Perlmutter and Myers (1979) reviewed the research on recognition memory in the years prior to five and found that age-related increases in performance, if they occur at all, can be attributed to (1) acquisition factors such as more efficient scanning, encoding and information pickup;

(2) knowledge factors -- if the items are differentially familiar to the older and younger children a developmental trend accrues; (3) comparison factors, such as matching; and (4) response factors, such as response bias changes with age. In general, Perlmutter and Myer's early recognition memory studies suggest excellent performance if the materials are familiar and the items distinct. There are no age differences under such circumstances. Age differences become apparent, when the stimuli are complex and/or differentially familiar and when sustained, systematic scanning and comparison processes are required.

A similar pattern emerges when older children serve as subjects. Dirks and Neisser (1977) asked adults and children from grades 1, 3, and 6 to view complex scenes and then tested them on recognition items with elements of the scene deleted or rearranged. There was a sizable improvement in performance as a function of age. On the basis of these data, Dirks and Neisser rejected the notion that picture recognition is a "unitary or automatic process that undergoes no development." Recognition performance improved with age, and the cause of its improvement depends on the particular kind of information being tested (i.e., the nature of the materials).

Not only did the nature of the materials affect the developmental trend but also the differential use of strategies. Dirks and Neisser found that their older subjects had at their disposal various strategies useful for picking up and storing the kinds of information the test required. Older children were more likely to scan the array systematically, to notice that neighboring items can form meaningful groups, to pay attention to nuances of spatial arrangement, or to formulate verbal descriptions of

minor details. Dirks and Neisser conclude that "recognition is not based on automatically encoded visual traces; it depends on specific and gradually developing cognitive skills."

The work of Jean Mandler and her colleagues confirms the picture: Mandler has been interested in recognition memory for complex visual arrays that are organized or disorganized (Mandler & Johnson, 1977; Mandler & Ritchey, 1977; Mandler & Robinson, 1978) and for orientation and spatial information in complex pictorial arrays (Mandler & Day, 1975; Mandler & Parker, 1976; Stein & Mandler, 1974; Mandler & Stein, 1974; for a review of their work, see Mandler, this volume). For our purposes here, it is sufficient to state that the improvement with age found in these complex recognition memory tasks is a function of changes in the nature to the materials (stimulus complexity), scanning strategies, and knowledge.

The accumulated literature suggests that recognition memory is clearly not impervious to developmental differences. A prime determinant of levels of performance is the nature of the stimulus materials and the relationship among target and distractor items. By cleverly manipulating the compatibility of the stimulus materials with the child's existing knowledge, it should be possible to generate any pattern of age effects in recognition. For example, one might adopt Chi's (1978) procedure and manipulate stimulus familiarly in such a way that younger children are the experts and hence can recognize what to the older novice look like very similar stimuli. Or one could vary the similarity of the distractor and target items along some scale of semantic similarity not yet salient to the young but distracting to the old. The less mature child would not be snared by the "related" distractor and should outperform the confused older participant.

In summary, the recognition memory literature provides an excellent illustration of the interactive nature of the tetrahedral framework. To predict performance on any recognition task, one would need to know something about the nature of the actual task (number of distractors, response demands, etc.), the nature of the materials (the relationships between target and distractor items), the compatibility of the organization in the material with the child's extant knowledge, and the demands placed on active strategies, such as scanning and systematic comparison processes (Brown & DeLoache, 1978).

D. The Criterial Task

We turn now to the last entry in our tetrahedral framework, the criterial task. Learning is not undertaken in a vacuum; there is always an end product in mind, and effective learners are often cognizant of this end product and tailor their learning activities accordingly (Bransford, 1979; Brown, 1979, 1982; Meacham, 1972). For example, to be effective in a memory task, learners need to know whether the demand is for gist rather than for verbatim recall, for recognition rather than reconstruction. They need to know if memory for the material is required as the end product or whether they will be called upon to apply the acquired information to novel instances (Bransford, 1979; Nitsch, 1977). In short, learners' activities are purposive and goal-directed and the nature of the criterial task will play an important role in determining the effective activity that must be undertaken.

It follows, then, that an appropriate learning activity must be one that is compatible with the desired end state. One cannot, therefore, discuss appropriate learning activities unless one considers the question

"appropriate for what end?," or the compatibility between the learning activity and the goal of that activity. Effective learners tailor their strategies in tune with changes in task demands. And there is a great deal of evidence in the educational research literature that the more the student knows concerning the criterial task to which her knowledge must be put, the better the outcome of reading and studying (Baker & Brown, in press b; Anderson & Armbruster, in press).

Consider the following example from Bransford, Stein, Shelton, and Owings (1981) concerning where and when a certain strategy is appropriate. Imagine that students are given a passage about blood circulation and that they must learn to differentiate between arteries and veins, that arteries are thick, elastic and carry blood from the heart that is rich in oxygen; veins are chinner, less elastic, and carry blood rich in carbon dioxide back to the heart. To the biological novice, even this relatively simple set of facts can seem arbitrary and confusing. Was it veins or arteries that are thin? Was the thin one or the thick one elastic? Which one carries carbon dioxide from the heart (or was it to the heart)?

There are several ways to deal with the problem of learning factual content that initially seems unfamiliar and arbitrary. One is simply to rote rehearse the facts until they are mastered, the brute force approach. Sometimes, a more efficient approach is to use various mnemonic elaboration strategies (Rohwer, 1973). For example, the fact that arteries are thick could be remembered by forming an image of a thick, hollow tube that flashes "artery." An alternate technique is to use verbal elaboration; for example, Art(ery) was thick around the middle so he wore pants with an elastic waistband..." There is a considerable amount of literature

documenting the fact that the formation of images and linking sentences can facilitate retention (Reese, 1977) and researchers have also explored the possibility of explicitly teaching various mnemonic techniques in order to improve people's abilities to learn (Rohwer, 1970; Weinstein, 1978).

Mnemonic techniques are useful for remembering facts about veins and arteries, but one may have to take a very different approach to learning in order to develop an understanding of the functions of veins and arteries; an understanding that would be necessary if the criterial task were not remembering facts but, for example, designing an artificial artery. If students used only mnemonics, however clever, intended to produce rote recall of facts, they would not necessarily be prepared for a criterial task demanding understanding of principles.

In order to understand, learners must seek information about the significance or relevance of facts. For example, the passage about veins and arteries stated that arteries are elastic. What's the significance of elasticity? Because arteries carry blood from the heart, there is a problem of directionality. Why doesn't the blood flow back into the heart? This will not be perceived as a problem if one assumes that arterial blood always flows downhill, but let's assume that our passage mentions that there are arteries in the neck and shoulder regions. Arterial blood must, therefore, flow uphill as well. This information might provide an additional clue about the significance of elasticity. If arteries expand from a spurt of blood and then contract, this might help the blood move in a particular direction. The elasticity of arteries might, therefore, serve the function of a one-way valve that enables blood to flow forward but not backward. If one were to design an artificial artery it might, therefore,

be possible to equip it with valves and hence make it non-elastic. However, this solution might work only if the spurts of blood did not cause too much pressure on the artificial artery. Suppose that our imaginary passage does not provide enough information about pressure requirements; if so, the learner would have to look elsewhere for this information. Note, however, that an efficient learner would realize the need to obtain additional information. The learner's activities are not unlike those employed by good detectives or researchers when they confront a new problem. Although their initial assumptions about the significance of various facts may ultimately be found to be incorrect, the act of seeking clarification is fundamental to the development of new expertise. In contrast, the person who simply concentrates on techniques for memorizing facts does not know whether there is something more to be understood (Bransford et al., 1981).

This somewhat detailed example illustrates that the nature of the criterion task determines the appropriate processing strategy. If the desired outcome is rote recall, perhaps the most appropriate strategy is mnemonic elaboration; if, however, the desired outcome is comprehension of the significance of information contained in the material or the application of the information to a novel problem, then the appropriate activity would change. Consider an experimental example from Nitsch (1977). Students heard definitions of six new concepts (such as, to minge: to gang up on a person or thing) and then received a series of study-test trials that required them to identify examples of each concept. Students in one group learned the concepts in the same contexts; each of the examples for a particular concept was drawn from a common context (all

examples of "minge" involved restaurants, examples of "crinch" involved cowboys; etc.). Students in the second group also learned the concept definitions but they were presented in varied contexts (examples for "minge" might, therefore, range over restaurant contexts, cowboy contexts, and so forth). After students had learned the concepts, they were asked to rate their degree of mastery. There were no differences between the groups, and students in both groups were relatively confident that they knew the concepts, which they did by some criteria. They were then given a new test requiring them to identify examples of concepts that occurred in novel contexts, contexts never experienced during acquisition. Students who had received the varied context training performed much better on the new test. Varied context experience was a better preparation for the actual criterial task of using the concept, whereas same context experience produced faster rote learning of the particular exemplar in the original task.

An important aspect of Nitsch's study is that students who received training on same context examples had an inaccurate and overinflated "sense of mastery." However, one does not want to argue that students in Nitsch's same context condition had fewer "metacognitive skills" than students who received the varied context training. A much more plausible interpretation is that students who received same context training had set up inappropriate expectations concerning the actual criterial task, i.e., they were expecting a test that was similar to their acquisition training but not anticipating the type of transfer task actually administered. Their assessment of mastery was accurate given their assumptions about the type of criterial task to be performed.

Nitsch asked the students to rate their feelings of mastery a second time; this time after they had taken the transfer test. Under these conditions the sense of mastery ratings for the same context students were lower than those of the varied context students. Thus, an important question concerns the degree to which students learn something when confronted with a criterial task that they are not prepared to handle adequately. For example, imagine that students in Nitsch's same context condition had taken the transfer test and were then asked to learn six additional concepts. Assume further that they could structure their own acquisition activities, ask questions, and so forth. Would these students inquire about the nature of the test? Would they learn in a way that would enable them to identify novel examples? In other words, would they modify their learning strategy in light of their new found knowledge concerning the actual nature of the criterion task?

A recent study by Bransford and his colleagues (Bransford et al., 1981) is relevant to the present discussion. They presented academically successful and less successful fifth graders with pairs of sentences. One member of each pair was completed with a precise (or meaningful) elaboration (e.g., The hungry man got into the car to go to the restaurant), the other with an imprecise (or random) elaboration (e.g., The hungry man got into the car to go for a drive). Children were shown that each pair of sentences was about a different type of man (hungry, short, etc.) and were informed that their task was to choose the member of each pair that would make it easier to remember which man did what (see also Tenney, 1975).

The majority of academically successful fifth graders performed like college students and chose the sentences that were precisely elaborated. In contrast to the successful students, all but one less successful student chose sentences on the basis of something other than "precision." Most chose the sentence that was shorter because they felt that shorter items would be easier to remember. This is a reasonable hypothesis, of course.

On a subsequent memory test, the children were much better at remembering precise sentences; they, therefore, had an opportunity to use their memory performance to evaluate their original hypotheses about the variables that influenced sentence memory. The few successful students who initially had not entertained hypotheses about precision changed their hypothesis on the second set of sentence pairs; they chose the precise sentences and adequately explained why. One less successful student changed his hypothesis after the first test and focused on precision; the rest of the less successful children made no change at all. These data are consistent with other reports that immature learners often fail to revise hypotheses in the face of conflicting information, or fail to change their strategies after doing poorly on a test (Belmont & Butterfield, 1977; Brown, Smiley, & Lawton, 1978). The ability to modify one's activities in light of changes in the criterial task is an essential factor in efficient learning.

E. Summary

We have argued that in order for psychologists to fully understand learning, it is necessary to design experiments that are sensitive to the four points of the tetrahedral model. We would like to argue that just as psychologists need to understand how the four points interact (Jenkins,

1979), so, too do learners. On her road to becoming an expert in the domain of intentional learning, the child will be greatly helped if she can develop the same insights into the demands of the tetrahedral model that the psychologist needs. To be an effective learner, she will need to know something about her own characteristics, her available learning activities, the demand characteristics of various learning tasks, and the inherent structure of materials (Flavell & Wellman, 1977). She must tailor her activities finely to the competing demands of all these forces in order to be a flexible and effective learner. In other words, she must learn how to learn.

The use of terms such as "know," "be aware of," etc., brings us face-to-face with the controversial topic of metacognition in its various manifestations. As this is a popular area of research, we will turn in Section IV to a relatively in depth treatment of some of the issues.

IV. Metacognition, Executive Control, Self-Regulation, and Other Even More Mysterious Mechanisms[1]

A. What is Metacognition

In this section, we will describe some of the historical roots and discuss the current status of the fashionable but complex concept of metacognition and other topics with which it shares a family resemblance. Various forms of metacognition have appeared in the literature and some of these instantiations are puzzling and mysterious. For example, Marshall and Morton (1978) refer to the mechanism that permits the detection and correction of errors in speech production as an EMMA, or "even more mysterious apparatus," that could be an "optional extra." We will argue that far from being an optional extra, the processes that have recently earned the title "metacognitive" are central to learning.

Metacognition refers to one's knowledge and control of the domain cognition. Two primary problems with the term are that (1) it is often difficult to distinguish between what is meta and what is cognitive and (2) there are many different historical roots from which this area of inquiry arose.

Consider first the interchangeability of cognitive and metacognitive functions. Recent reviews of the literature on, for example, metacognition and reading have been justly criticized on the grounds that they have encouraged the practice of dubbing as metacognitive any strategic action. For example, metacognitive skills of reading include the following activities previously dignified with the title of mere strategies -- establishing the purpose for reading; modifying reading rate because of variations in purpose; identifying important ideas; activating prior knowledge; evaluating the text for clarity, completeness and consistency; compensating for failures to understand, and assessing one's level of comprehension (Baker & Brown, in press b). Just which of these activities should be deemed metacognitive, or, more subtly, which components of these complex activities are meta, is not clear.

A second source of confusion concerning the widespread use of the term metacognition is that, within the modern psychological literature, it has been used to refer to two distinct areas of research, namely knowledge about cognition and regulation of cognition. The two forms of metacognition are indeed closely related, each feeding on the other recursively; attempts to separate them lead to oversimplification. However, they are readily distinguishable, and they do have quite different historical roots.

Knowledge about cognition refers to the relatively stable, statable, often fallible, and late-developing information that human thinkers have about their own cognitive processes and those of others (Flavell & Wellman, 1977). This form of knowledge is relatively stable; one would expect that knowledge of pertinent facts about a domain, for example, memory (that it is fallible, that is is severely limited for short-term verbatim retention, etc.), would be a permanent part of one's naive theory on the topic. This form of knowledge is often statable, in that one can reflect on the cognitive processes involved and discuss them with others. Of course, this form of knowledge is often fallible, in that the child (or adult for that matter) can perfectly well "know" certain facts about cognition that are not true. Naive psychology is not always empirically supportable. Finally, this type of knowledge is usually assumed to be late developing, in that it requires that learners step back and consider their own cognitive processes as objects of thought and reflection (Flavell & Wellman, 1977).

The second cluster of activities dubbed metacognitive in the developmental literature consists of those used to regulate and oversee learning. These processes include planning activities prior to undertaking a problem (predicting outcomes, scheduling strategies, and various forms of vicarious trial and error, etc.), monitoring activities during learning (testing, revising, and re-scheduling one's strategies for learning) and checking outcomes (evaluating the outcome of any strategic actions against criteria of efficiency and effectiveness). It has been assumed that these activities are not necessarily statable, somewhat unstable, and relatively age independent, i.e., task and situation dependent (Brown, 1978, 1980, in press b).

Although knowledge and regulation of cognition are incestuously related, the two forms of activity have quite different roots and quite different attendant problems. The tension generated by the use of the same term, metacognition, for the two types of behavior is well illustrated by the fact that even the leading proponents in the field tend to answer questions about the nature of metacognition with "it depends." Is metacognition late developing? -- it depends upon the type of knowledge or process referred to; is metacognition conscious? -- it depends, etc. In the next section we will consider four separate stands of inquiry where the current issues of metacognition were introduced and originally discussed.

B. Roots of Metacognition

We will discuss four historically separate, but obviously interlinked, problems in psychology that pertain to issues of metacognition. First, there are the enduring questions concerning the status of verbal reports as data (Ericsson & Simon, 1980). Can people have conscious access to their own cognitive processes? Can they report on these processes with verisimilitude? And how does the act of reporting influence the processes in question? Second, there is the issue of executive mechanisms within an information processing model of human and machine intelligence. What is responsible for regulation of cognition? With what knowledge or form of knowledge must an executive be imbued? How do such models deal with the infinite regression of homunculi within homunculi? And with the problems of consciousness, intention and purpose? Third, we will deal with the issues of self-regulation and conceptual reorganization during learning and development that have always been featured in Genevan developmental psychology and have played a major role in Piaget's modern writings (1976,

1978) and those of his co-workers, notably Karmiloff-Smith (1979 a,b; Karmiloff-Smith & Inhelder, 1974/75) and Inhelder (Inhelder, Sinclair, & Bovet, 1974). And, finally, we will discuss the transference from other-regulation to self-regulation central to Vygotsky's (1978) theory of development.

1. Verbal Reports as Data. Several theorists from quite disparate schools agree that the most stringent criteria of understanding involve the availability of knowledge to consciousness and reflection, thus permitting verbal reports (Brown, 1982; Brown & Campione, 1981; Rozin, 1976). Early investigations into children's knowledge about cognition focused on metamemory; many studies relied on the direct approach of simply asking children to report what they knew. Kreutzer, Leonard, and Flavell (1975) interviewed children in kindergarten and grades one, three, and five about the effects of a number of variables on remembering. They found that even the youngest subjects knew that information in short term memory can decay rapidly, that the relearning of forgotten information tends to be faster and easier than the original learning, that study time affects subsequent retrieval attempts, and that the number of items and their familiarity also affect retention. Children at all ages tended to rely on external mnemonic resources (e.g., other persons, notes) rather than internal ones. Third and fifth graders seemed to be more planful and self-aware; they suggested a greater variety of mnemonic strategies, and showed better understanding of the potential interactions among variables in their effects upon memory. Wellman's (in press) findings that 10-year-olds were far better than 5-year-olds in judging the interaction of two memory relevant variables, although not in judging the effect of a single

variable, are consistent with the results of Kreutzer et al.

Even preschoolers have some information concerning what makes a memory task easy or hard (Wellman, 1977); they come to understand the memory relevance of certain variables according to the following developmental sequence: (1) number of items, (b) distraction, (c) age of rememberer, assistance from others, study-time, and (d) associative cues. Wellman also found that the knowledge that certain factors (e.g., body-build, type of clothing, etc.) are irrelevant to memory increased from ages 3 to 5 years. Wellman suggested that children will tend more easily to recognize the role of a relevant variable if it occurs frequently in their own experience. if it concerns their own behavior, and if its various manifestations are easily discriminable to the young child.

Since the original questionnaire studies, a great deal of evidence has accumulated that demonstrates older children's greater knowledge about memory (Flavell & Wellman, 1977), attention (Miller & Bigi, 1979), communication (Yussen & Bird, 1979), reading (Baker & Brown, in press a; Markman, 1979; Myers & Paris, 1978), studying (Baker & Brown, in press a; Paris & Myers, 1981), problem solving (Piaget, 1976), etc. As Kreutzer et al. (1975) point out, questionnaire studies provide an interesting insight into the child's understanding of a particular domain; however, these data should be followed with careful empirical examination of the phenomena in question.

As part of a body of converging evidence, verbal reports of cognitive processes are extremely valuable. But there are nontrivial problems associated with reliance on self-reports in the absence of corroboration. An obvious problem is the difficulty associated with asking children to

inform on the content of their own conscious processes. As Piaget and others have pointed out, children are as likely to distort and modify their observations of their thought processes as they are their observations of the world around them. Eyewitness testimony is fallible, no less for the objects and events of the internal world than for the external.

Another problem concerns reliability. Will children be consistent in their opinions and beliefs about cognitive processes? Few investigators have considered the problems of reliability or validity, an equally thorny problem. What is the relationship between what an informant says and what she does? Studies with children have yielded only a moderate relation, for example, between performance on a restricted class of memory tasks and children's statable knowledge of (sometimes a different) class of memory phenomena (Cavanaugh & Borkowski, 1979; Justice & Bray, 1979; Kelly, Scholnick, Travers, & Johnson, 1976; Kendall, Borkowski, & Cavanaugh, 1980; Salatas & Flavell, 1976); although there have been some recent studies where a clearer relationship was found (Perlmutter, 1978· Waters, in press). In many of these studies the rationale for why one would expect a link between the particular form of metamemory probed and actual performance is weak (Wellman, in press). Similarly, as Flavell and Wellman (1977) point out, there are many reasons why there should not be a close link between metamemorial knowledge and memory performance in any one particular task.

Many forms of knowledge about things cognitive can be assumed to be stable, others transient and elicited only in certain situations. Stable forms are the kinds of declarative knowledge learners may possess about themselves (and others) in the learning context, the tetrahedral model if

you will. People know about the demands of certain classes of problems and the necessity of tailoring their learning activities finely in tune with specific criterial tasks. These are the types of knowledge that Flavell and his colleagues (Flavell, 1981; Flavell & Wellman, 1977) have classified as person, task and strategy variables. Learners possess naive theories of what it takes to learn certain classes of materials and to meet certain criterial task demands, as well as theories of their repertoire of available strategies to accomplish certain ends, etc. That young children are less informed about stable characteristics of learning is amply documented (for reviews see Baker & Brown, in press a,b; Brown, 1978, 1980; Cavanaugh & Perlmutter, 1982; Kluwe, in press; Kreutzer et al., 1975; Flavell & Wellman, 1977; Weinert, in press; Wellman, in press).

Transient forms of knowledge include insights that are elicited while actually performing a particular task; with adult subjects this is often the form of information obtained from on-line talk aloud protocols. Protocol analyses of performers actually solving problems have been restricted to adult subjects or adolescents, supposedly because young children are judged to be incapable of the split mental focus that is required for simultaneously solving problems and commenting on the process. Instead, developmental psychologists have typically asked children to predict what they will do in imaginary situations. For example, preschool and early grade school children have difficulty predicting their span for lists of pictures (Flavell, Friedrichs, & Hoyt, 1970; Markman, 1973; Worden & Sladewski-Awig, 1979; Yussen & Levy, 1975), and they are likely to predict that categorized lists are as easy to recall as random ones (Moynahan, 1973; Yussen, Levin, Berman, & Palm, 1979). Predicting in

advance of an actual trial is difficult for the young, although they do seem better able to report retrospectively on their own actually experienced performance (Brown & Lawton, 1977: Moynahan, 1973), and do take this information (and false norms about other learners) into account when predicting again (Brown, Campione, & Murphy, 1977: Markman, 1973: Yussen & Levy, 1975).

But it is a common and problematic procedure in the developmental literature to ask children to describe how they would behave in certain hypothetical situations. Asking adult informants to imagine possible worlds and how they might act in them is one of the practices highlighted by Nisbett and Wilson (1977) in their attack on the status of verbal reports as data; it was also heavily criticized by Ericsson and Simon (1980). But the questionnaire studies of children's knowledge consist primarily of situations in which the child must imagine scenarios and how she might act in them. Of the fourteen main items contained in the Kreutzer, Leonard and Flavell (1975) questionnaire, ten are completely imaginary, e.g., the child is asked to imagine how other children might perform in a task. It might help to clarify matters if a distinction were made between (1) predictive verbalizations about possible performance before the event; (2) concurrent verbalizations as one is actually performing; and (3) retrospective verbalization after the event has transpired.

Another important distinction is whether information is being sought concerning specific or very general knowledge. Questions of the form "How do you perform these tasks?" implicitly request very general information and leave open to the informant the creative task of constructing a general

rule by drawing on a variety of specific experiences, including general knowledge of what one ought to do in such tasks. As Ericsson and Simon (1980) point out, in areas of applied psychology where verbal questioning has a long history, subjects are rarely asked for their general theories or impressions. Instead, Flanagan (1954) and others used what is referred to as the critical incident technique whereby informants are asked to report only about very specific incidents. For example, combat pilots would be asked to describe a particular, actually experienced incident, and then to answer questions on how they thought or felt within that specific event. In general, however, questionnaire and experimental studies of children's metacognition demand reflection on quite general cognitive processes. Asking children to describe general processes that they might use in imaginary situations is the least favorable circumstance for producing verbal reports that are closely linked with the cognitive processes under discussion.

Finally, an adequate theory of the relation of verbal reports to actual performance should include some a priori predictions of when verbal reports will be related to or will influence performance and when they will not. Ericsson and Simon (1980) believe that verbal reports will have a positive, negative or neutral effect on performance depending on the function of the reports in the ongoing learning process. The effect will be neutral under circumstances where the subject is asked to describe information that is already available (i.e., in STM). If the subject is asked to report on information that is available but not in verbal or propositional form, the translation process may slow down performance but will not otherwise interfere. Ericsson and Simon quote a great deal of experimental evidence to support these claims.

Of greater interest are situations where the relation between "thinking aloud" and problem solving can be beneficial. This occurs most commonly when the type of verbalization that is required is a statement of a rule, or a reason for an action. Good problem solvers (adults) spend more time than poor learners identifying and evaluating what they did or are doing, stating rules and evaluating their efficiency (Dorner, 1978; Goldin & Hayes-Roth, 1980; Thorndyke & Stasz, 1980). And, on standard laboratory puzzles such as the Tower of Hanoi, instructions to state a rule significantly accelerate the learning process and facilitate transfer across isomorphic and homomorphic versions of the same physical puzzle (Gagné & Smith, 1962) or story problem (Gick & Holyoak, 1980). Although there is little data, the same effect seems to work for children. On mathematic problems requiring invention (Resnick & Glaser, 1976), Pellegrino and Schadler (1974) required children to "look ahead" by verbalizing a sequence of goals, a procedure that produced a dramatic increase in the number of successful inventions by grade school children. And, in an ongoing study, Crisafi and Brown (work in preparation) found greater transfer across problem isomorphs of an inferential reasoning task when three- and four-year-old learners were required to describe the solution after each problem (to Kermit the frog so that Kermit could also do the task).

Verbal reports can often have a <u>negative</u> effect on the learning process. Prime examples of such situations are where the requirement for overt verbalization competes for central processing capacity with the processes that must be reported. In on-line protocols it is characteristic that verbalization stops when the going gets difficult and starts up again

when the cognitive load is lessened. Similarly, requiring verbal reports of information that is not generally available to consciousness is a disruptive procedure. For example, one reason why Piaget (1976, 1978) experienced so much difficulty getting children to describe their actions may be because the subjects of those descriptions were just that, actions. Perceptual motor activities are notoriously difficult to describe, and it is, indeed, true that we can do a great deal that we cannot describe (Broadbent, 1977). And, as many current information processing models claim, many of the intermediate steps of both thought and action become automatized with repeated practice, and, thereby, even less available to conscious introspection (Norman & Schallice, 1980; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Asking subjects to report on internal events that are not readily available to such inspection can significantly impair the processes upon which they must report.

In summary, desperately needed in the developmental literature are systematic evaluations of children's verbal reports on their own cognitive processes when stringent attention is paid to (1) the temporal relation between these reports and the cognition in question, (2) the nature of the cognitions under evaluation, and (3) the influence of reflection on the operations of thought. It is simplistic to ask whether or not a certain group of children have reflective access to their own cognitions without specifying exactly the conditions under which these observations are made. Ideally one would like to see programmatic research aimed at uncovering a certain child's range of understanding within a task domain. Under what conditions is it reasonable to ask for verbal reports? Can the child make predictive, concurrent, or retrospective statements about actual or

potential cognitive activity within a problem space? Do the specific restrictions on adults' verbalizations under varying circumstances apply to children, or do young learners experience particular difficulties with, for example, imagining possible actions in situations as yet unexperienced? Do children have particular problems talking about general rules rather than specific activities? In short, we need to progress from the current piecemeal study of certain isolated metacognitions concerning intuitively appealing but somewhat haphazardly chosen cognitive tasks, to a systematic evaluation of the function of verbal reports in specific learning situations. Such data would provide an invaluable source of evidence concerning what a child knows, when she knows it, and how knowing influences performance.

2. Executive Control. The second historical root of things metacognitive is the notion of executive control taken from information processing models of cognition. The majority of information processing models attribute powerful operations to a central processor, interpreter, supervisor, or executive system that is capable of performing intelligent evaluation of its own operations:

> The basic requirements of such an executive demonstrate the complexity of the issue. It must include the ability to (a) predict the system's capacity limitations, (b) be aware of its repertoire of heuristic routines and their appropriate domain of utility, (c) identify and characterize the problem at hand, (d) plan and schedule appropriate problem-solving strategies, (e) monitor and supervise the effectiveness of those routines it calls into service, and (f) dynamically evaluate these operations in the face of success or failure so that termination of activities can be strategically timed (Brown, 1978, p. 152).

Thus, very complex operations are attributed to something within the system, a problem of attribution that is, to say the least, theoretically problematic (Boden, 1978; Dennett, 1978).

Information-processing theories emerged in the mid-sixties, along with the growing interest in computer competence and machine simulation of thought. The concurrent development of psychological models was greatly influenced by the theories and jargon of synthetic intelligence, and the computer metaphor has dominated theories of human cognition during the past fifteen years. By adopting the notion of a central processor or executive system imbued with very fancy powers, developmental psychologists gained a powerful analogy through which to consider the development of efficient learning. (For a detailed review of information-processing models and developmental psychology, see Klahr & Wallace, 1976; Siegler, 1981; also see Siegler, companion volume.)

Central within the prototypical information processing model are the concepts of executive control, whether implicitly or explicitly stated, and automated and controlled processes; these notions are interlinked. We will describe the automated-controlled distinction and then the executive systems.

Automatic and Controlled Processes. A two-process approach to thinking predates information-processing models. A notably lucid description of the distinction between automatic and controlled process was provided by James (1890) who stressed the freedom from attention and effort that automatization provides: "The more details of our daily life we can hand over to the effortless custody of automatism, the more our higher powers of mind will be set free for their own proper work."

Automatic processing is a fast, parallel process, not limited by short-term memory, that requires little subject effort, and demands little direct subject control. Controlled processing is a comparatively slow,

serial process, limited by short-term memory constraints, requiring subject effort, and providing a large degree of subject control (Schneider & Shiffrin, 1977).

The distinction between automatic and controlled processing is now a common feature of both the adult and developmental literatures, although it masquerades under different titles. For example, in the adult literature are Posner and Snyder's (1974) "conscious strategies" and "automatic activation," Shiffrin's (1975) "controlled vs. systemic processing," Norman and Bobrow's (1975) "resource limited" and "data limited processing," and LaBerge's (1975) "automatic focusing." Nineteen-seventy-five was obviously a good one for this theoretical concept. More recent theories come from Shiffrin and Schneider (1977) and Logan (1978, 1979). Developmentalists also discuss "deliberate and involuntary" (Brown, 1975), "effortful and automatic" (Hasher & Zacks, 1979) and "strategic versus automatic" (Naus & Halasz, 1979) processing.

There are many interesting questions for developmental psychologists concerning automatization. A major notion is that a great deal of the development that occurs with increasing expertise (age) is the result of processes that were originally controlled, effortful and laborious becoming automated (Brown, 1975; Hasher & Zacks, 1979; Naus & Halasz, 1979; Shiffrin & Dumais, 1981). A second well-aired notion is that processes that do not demand a great deal of strategic control are efficient even in the young and are less sensitive to developmental changes (Brown, 1975; Hasher & Zacks, 1979). But of particular interest in this section is the notion of who or what does the controlling, and who or what deciphers the output of the automatized system.

Heterarchies, Hierarchies, and Demons All the Way Down. Within the information processing system, executive power in large or small degrees must be attributed, and it is with this attribution that the models run into epistemological problems of long standing, problems that have proven particularly recalcitrant and uncomfortably metaphysical for a psychology never truly weaned from a strict radical behaviorist tradition. The major problem is the traditional one of consciousness and who has it. The problem is nicely stated by Norman in his inaugural address to the Cognitive Science Society:

> Consciousness is a peculiar stepchild of our discipline, agreed to be important, but little explored in research and theory. There are legitimate reasons for this relative neglect. This is a most difficult topic, one for which it is very difficult to get the hard, sensible evidence that experimental disciplines require . . . We cannot understand (thinking) until we come to a better appreciation of the workings of the mind, of the several simultaneous trains of thought that can occur, of the differences between conscious and subconscious processing, of what it means to focus upon one train of thought to the exclusion of others. What-who-does the focusing? -- And what does it mean to have conscious attention? Can there be attention that is not conscious? What -- who -- experiences the results of conscious attentional processes? (Norman, 1980, p. ???)

Norman's self-conscious use of "who" or "what" immediately conjures up a spectre traditionally feared and derided by psychologists, the ghost in the machine, the homunculus. Skinner refers to this entity as the "inner man" whose function is "to provide an explanation which will not be explained in turn" (Skinner, 1971, p. 14). Such theories are, indeed, easy to deride, but hard to replace with an alternative. As Dennett (1978) points out (see also Boden, 1972, 1978), Skinnerian outrage at such "mentalisms" can be reduced to the axiom, "don't use intentional idioms in psychology." It is one of the liberations of current theories of cognitive science that we admit that human beings are intentional and that an

adequate explanation of human behavior necessitates reference to the intention, or the meaning of the behavior to the individual who performs it, i.e., the individual's understanding of what she is doing (Boden, 1977; Brown, 1982; Dennett, 1978; Flores & Winograd, 1978; Norman, 1980; Shaw & Bransford, 1977).

How do information processing models deal with the inner man? Most of the original models were hierarchical, uni-directional systems with a central processor initiating and interpreting lower level actions. More recent models tend to be heterarchical so that control can be distributed throughout the system (Hayes-Roth, 1977; Hayes-Roth & Hayes-Roth, 1979; Turvey & Shaw, 1979). Heterarchical control is clearly evident in animal physiological systems (Gallistel, 1980; Green, 1971; Turvey, 1977), skilled performance and action (Gallistel, 1980; Norman, 1981; Norman & Schallice, 1980; Turvey, 1977), and human speech perception (Turvey, 1977). Several recent theorists have claimed that heterarchies are the simplest class of system that could perform processing tasks of the complexity typical of human behavior (Gallistel, 1980; Green, 1971; Koestler, 1979; Turvey, 1977; Turvey, Shaw, & Mace, 1978).

Such systems do not rid themselves of inner men making decisions; the demons do not go away; they get distributed; a democratic solution that is much favored in current information processing models (Hayes-Roth & Hayes-Roth, 1979; Norman & Schallice, 1980) that trace their historical roots to Selfridge's (1959) original Pandemonium model. But, even within the democratic confederacies or heterarchies there are supervisory processors (Lindsay & Norman, 1977) or decision demons (Selfridge. 1959) who listen to the pandemonium produced by the lower level demons and select the most

obtrusive. Conflicts for attentional resources must occur when several subordinate processors compete for the same resources. Some conflict resolution procedure must be provided in such systems (Norman & Schallice, 1980; McDermott & Forgy, 1978); it is these conflict resolution devices that sound very like metacognitive demons to the untrained ear.

Planning. Most central to the issues of metacognition are computer planning models that attempt to model problem-solving behavior. The concept of planning was introduced to artificial intelligence by the programmers of General Problem Solver (Newell & Simon, 1972). The main planning strategy of GPS was means-end analysis, a hierarchical planning strategy that works backward from a clear idea of the goal to be achieved. GPS works quite well for closed problem systems that have well defined goals that can be reached by fixed means. But, GPS is a simple state-by-state planning strategy that does not produce an overall strategic plan of the problem before the solution is started. Such a decision maker has limited flexibility in revising and evaluating plans. Sacerdoti (1974) argues that although it is not sensible to formulate an epistemologically adequate plan before attempting problem solution, a broad outline of the plan should be scheduled first so that the system can see what adjustments need to be made during execution. Machine programs can no more foresee all possible contingencies than can humans and, therefore, some form of contingency planning is needed.

Sacerdoti's Network of Organized Action Hierarchies (NOAH) constructs a preplan that can be altered on a contingency basis during execution; NOAH works by means of a successive refinement approach to planning. But NOAH is essentially a "top-down" processor with the planner making high level

making high level abstract plans that guide and restrict the subsequent development of low-level details. Similarly, the model assumes that the initial plan is relatively complete and subject only to refinement at lower levels. NOAH is, therefore, essentially a hierarchical planning model.

Recently, Hayes-Roth and Hayes-Roth (1979) have developed an opportunistic planning model (OPM) that departs from the top-down, hierarchical, complete preplan assumptions of prior planning models. The OPM permits planning at many different levels, allows several tentative, incomplete plans to coexist and is, therefore, essentially a heterarchical system. The OPM has great flexibility, in that it can shift among several planning levels opportunistically. At any one point in the planning process, the planner's current decisions and observations afford new opportunities for plan development, and these are followed up by the model. Sometimes these opportunistic decisions result in orderly top-down routes, but often less coherent sequences are engaged in, just as in human thinking.

The OPM achieves this flexibility by assuming that the planning process consists of the independent actions of many distinct cognitive specialists (demons), each able to make tentative decisions for potential incorporation within a plan. As in the classic Pandemonium model (Selfridge, 1959), the specialists record these decisions in a common data structure known as the blackboard, thus enabling them to interact with each other, to influence and be influenced by each other's decisions.

The blackboard is divided into five conceptual planes that correspond to different categories of decision. These include: (1) metaplan decisions that deal with the general approach to the problem; (2)

plan-abstraction decisions that describe ideal plans, that may or may not be feasible, i.e., what kinds of actions are desirable; (3) plan decisions that cover what specific actions to take; (4) world-knowledge decisions that take note of specific problem environments; and (5) executive decisions that are involved with the on-line organization of the planning process itself. Each plane on the blackboard is also potentially served at several levels of aostraction. For example, the levels of the metaplan involve problem definition, selection of an appropriate problem-solving model, policy-setting, and establishment of appropriate evaluation criteria. The executive plan involves decisions of priority, scheduling, and general allocation of cognitive resources.

In a recent series of studies, Goldin and Hayes-Roth (1980) tested the OPM model by examining the planning strategies of adults. The task was to schedule a series of errands in a fictional town. The subjects read a scenario that described a series of desired errands, a starting time and location, an ending-time and location, and sometimes some additional constraints. The allotted time was invariably insufficient to perform all of the errands and, therefore, the planners were obliged to set priorities concerning which errands to perform as well as to organize their schedule in the most economical manner. The primary data consisted of the protocols of the subject's on-line descriptions of their planning processes.

Good planners made many more metaplan and executive decisions and exercised more deliberate control over their planning processes. Good planners also made more use of world knowledge information. They showed greater flexibility than poor planners in that they frequently shifted the focus of their attention among the different plans of decisions (within the

OPM framework) and among the different loci within the route. More of the decisions of good planners were at a high level of abstraction; good planners recognized the importance of global planning, in contrast to the heavy reliance on local control or bottom-up plans shown by the poor planners. Poor planners tended to switch back and forth between objectives in an idiosyncratic (and often chaotic) fashion. In contrast, effective planners developed a prototypical procedure for accomplishing the errands which they maintained over several instantiations of the task.

The details of GPS, NOAH, and OPM are not important for our purposes here; the lesson is that with increasing sophistication, information-processing and artificial intelligence models have gained more power by paying increasing attention to the "metacognitive" aspects of thinking. Crudely, all such models distinguish between preplanning and planning-in-action (Rogoff & Gardner, in press), planning and control (Hayes-Roth & Hayes-Roth, 1979), pre-action and trouble-shooting (Norman & Schallice, 1980), and planning and monitoring (Brown, 1978). Preplanning involves the formulation of general methods of procedure prior to the actual onset of action. During the ongoing attempt to solve the problem there is continual planning-in-action, trouble shooting, or control processing that involves monitoring, evaluating and revising. Intelligent systems, be they machine or human, are highly dependent on executive orchestration, resource allocation, and monitoring functions. Non-intelligent systems, be they inadequate programs or humans, are assumed to be deficient in these planning functions.

Poor problem solvers lack spontaneity and flexibility in both preplanning and monitoring. Extreme examples of planning deficits in

adults come from the clinical literature on patients with frontal-lobe syndrome. Such patients typically omit the initial pre-action component (Luria, 1966); they also experience extraordinary difficulty with error correction (Milner, 1964). Such patients have been described as simultaneously perseverative and distractible, a failure in intelligent focusing attributed to damage to the supervisory attentional mechanism or executive system (Norman & Schallice, 1980). Although pathological cases are extreme, many descriptions of young and retarded children's planning are very similar.

Developmental Studies of Monitoring. Currently, there is considerable interest in planning and monitoring processes, and developmental data to support the theoretical models are accumulating in a variety of domains, notably studies of social planning (Bruce & Newman, 1978; Newman. 1981), problem solving (Klahr, 1978; Klahr & Robinson, 1981· Klahr & Siegler, 1978), planning and monitoring during reading and studying (Bransford et al., 1981; Brown, 1980, 1981· Flavell, 1981; Markman, 1981) and training research designed to improve the ability to plan and monitor in the developmentally young (Brown, 1978; Brown & Campione, 1981; see Section V). We will illustrate with two related examples of on-line monitoring from the area of learning from texts: (1) comprehension monitoring while listening and reading and (2) effort allocation while studying.

Comprehension Monitoring is a topic that has received considerable attention and been subjected to a great deal of theoretical speculation (Baker & Brown, in press a,b; Bransford et al., 1981: Brown, 1980; Collins & Smith, in press; Flavell, 1981· Garner, in press; Markman, 1981, in press; Stein & Trabasso, in press), although the data base to support these

speculations is somewhat sparse. Studies by Markman reaffirmed a traditional claim (Thorndike, 1917) that children are surprisingly tolerant of ambiguities, inconsistencies and just plain untruths in passages they must listen to (Markman, 1977, 1979, 1981, in press) or read (Garner, in press). For example, Markman (1979) had children in third, fifth and sixth grades listen to short essays containing inconsistent information: they were then probed for their awareness of the inconsistencies. Some of the inconsistencies could only be noticed if the child made an inference, whereas others were quite explicit. Children in all grades were poor at reporting the inconsistencies, although they were somewhat more successful with the blatant problems. Markman also found that when children were specifically warned in advance that a problem might be present in the text, both third and sixth graders were more likely to report the inconsistency. Nevertheless, many children still failed to report the inconsistencies.

In a recent series of experiments, Garner and her colleagues (Garner, in press; Garner & Kraus, 1980; Garner & Taylor, 1980) have shown that junior high students, particularly those identified as poor readers, are also poor at evaluating texts for internal consistency. The students were asked to rate brief passages for ease of understanding and to justify whatever low ratings they gave. Poor readers were less likely to rate inconsistent text as difficult to understand although good readers were by no means proficient at this task. The poor readers were better at identifying comprehension problems that were due to difficult vocabulary items than to inconsistencies (Garner, in press).

Garner and Taylor (1980) also found differences in the amount of assistance required to notice inconsistencies. After reading a brief

passage, fourth, sixth and eighth graders were provided with increasingly more specific hints as to the source of difficulty. Even after the experimenter underlined the two sentences that conflicted with one another and told the child they did not make sense, fourth graders and older poor readers were rarely able to report the exact nature of the problem. However, the intervention did increase the likelihood that better readers would notice the inconsistency.

Listeners and readers are more likely to notice inconsistencies if they are in a single sentence (Garner & Kraus, 1980) or in adjacent sentences (Markman, 1979), than if they are separated by a more substantial body of text, suggesting that one common shortcoming in children's comprehension monitoring is a failure to consider relationships across noncontiguous sentences in a text. Although they may be capable of evaluating their understanding of single sentences, they still need to develop the skills to integrate and evaluate information across larger segments of text. Even college students may have difficulty with the more demanding task (Baker, 1979).

One possible problem with these studies is that children were required to report the inconsistencies, and their putative lack of sensitivity could be due to a reluctance to criticize, or to the general problems with verbal reports discussed earlier. This interpretation is a little far fetched, however, because the insensitivity is reported in studies that used button pressing (Markman & Gorin, in press), rating comprehensibility (Garner, in press), and replaying a recorded message (Flavell, Speer, Green & August, 1981) as the index of comprehension failure.

One method to avoid the problem of verbal reporting is to take on-line evidence of comprehension monitoring. For example, adults return to previously read information and make regressive eye movements when they encounter pronouns whose referents are unclear (Baker, 1979; Carpenter & Just, 1977; Garrod & Sanford, 1977), and they require more time to read paragraphs that violate conventional organizational structure (Greeno & Noreen, 1974; Kieras, 1978). When such on-line measures are used, children are credited with more sensitivity to textual anomalies. We will give two examples, one with quite young children listening to confusing tape-recorded messages, the other with older children reading confusing text. The similarity in pattern of results across disparate tasks and ages is striking.

Flavell et al. (1981) instructed kindergarten and second grade children to construct block buildings identical to those described on tape by a confederate child. Some of the instructions contained ambiguities, unfamiliar words, insufficient information, or unattainable goals. Children were encouraged to replay the tape as often as necessary in order to help them construct the buildings. The children were videotaped as they attempted to carry out the instructions, and the videotapes were analyzed for nonverbal signs of problem detection, i.e., looking puzzled or replaying the tape. The children later were asked if they had succeeded in making a building exactly like the confederate's and if they thought the other child did a good job in conveying the instructions.

As expected, the older children were more likely to notice the inadequancies in the messages than were the younger. Even though both kindergartners and second graders showed nonverbal signs of puzzlement at

appropriate points during the task, the kindergartners were less likely to report later that some of the messages were inadequate. Several other investigators have also reported on-line evidence of problem detection in listening tasks despite failures to report the inadequacies verbally (Bearison & Levey, 1977; Lloyd & Pavlidis, 1978; Patterson, Cosgrove, & O'Brien, 1980).

Turning to comprehension-monitoring while reading, Harris, Kruithof, Terwogt and Visser (1981) reported an analogous finding; eight and eleven year olds were asked to read passages that contained sentences that were or were not anomalous depending on the title. For example, the sentence "He sat in the chair and watched his hair get shorter" would be acceptable if the title were "A Visit to the Barber," but anomalous if the title were "A Visit to the Dentist." Children at both ages read the anomalous sentence more slowly but the proportion of subjects reporting that they had detected a text problem was much greater in the eleven-year-old sample. This finding has also been reported by Capelli and Markman (1980); of interest in their study was that sixth graders decreased their reading time more dramatically than third graders in response to text anomaly. Capelli and Markman, Flavell et al. (1981), and Harris et al. (1981) all suggest that younger students have difficulty interpreting their own feelings of discomfort in the face of hitches in smooth comprehension.

One problem then with estimating children's comprehension monitoring ability is the measure that is used for assessing sensitivity; on-line measures, such as time expended, facial signs of confusion, etc. reveal earlier sensitivity than the more stringent demands for verbal reporting. A second problem is that familiarity of materials or knowledge base factors

are extremely influential in both listening and reading (Patterson, O'Brien, Kister, Carter, & Kotsonis, in press; Stein & Trabasso, in press). If children are familiar with the domain in question, they are more likely to note inconsistencies and to devise plausible hypotheses on how to resolve them. Furthermore, the development of the ability to monitor one's comprehension is not due to the development of a unitary "metacognitive faculty" or "demon" that automatically sounds an alarm at every possible misinterpretation or lack of mastery. One of the difficulties of constructing such a "comprehension-monitoring" demon to assess the adequacies of one's current state of understanding and mastery is that different information is necessary for different purposes. For example, nearly all adults know the concept of gold (as in gold watch or gold bar) and most adults would also confidently proclaim they knew the concept (Miller, 1978); indeed, they do know it sufficiently well for many purposes. If forced to differentiate real gold from fool's gold, however, most would quickly realize the need for more information. Technical concepts of gold are necessary for some purposes, but most adults experience no difficulties with their non-technical knowledge of gold. If a "comprehension-monitoring" demon sounded an alarm at anything less than non-technical knowledge, it would be an extreme pain in the head (or elsewhere depending on one's theory of localization).

In summary, the ability to monitor one's comprehension of texts is not just a function of age. The blatancy of the anomaly, its centrality to the reading task at hand, relevant background information, and the ability to interpret correctly the discomfort generated by various degrees of misunderstanding are all important factors determining efficiency. An

important point here is that obtaining non-verbal measures of comprehension monitoring is an important addition, because such non-verbal measures are often more sensitive to on-line monitoring than retrospective reporting.

Effort and Attention Allocation. Another non-verbal method of measuring on-line monitoring is to observe how learners deploy their attention and effort. The ability to attend selectively to relevant aspects of a task is a traditional index of learners' understanding of that task, be it discrimination learning (Crane & Ross, 1967; Hagen & Hale, 1973; Zeaman & House, 1963), rote memorizing (Hale & Alderman, 1978; Hagen & Hale, 1973), or learning from texts (Brown, 1981). Shifting attention as a response to increments in learning is a non-verbal reflection of on-line monitoring that can be examined developmentally. For example, consider such a shift in a rote memory task. Belmont and Butterfield (1977) observed students who were trained to use (or who spontaneously devised) a cumulative rehearsal strategy for remembering lists of digits. Without warning, a particular list was presented repeatedly, a departure from the usual procedure of presenting a novel list on each trial. Clear developmental differences were found in the speed and efficiency with which the students (a) abandoned the strategy when it was no longer needed (i.e., the list was learned) and (b) modified the strategy when it was appropriate (when lists composed of old and new segments were used). The link between effective monitoring and effort-allocation was quite clear.

There is considerable evidence in the educational literature that good learners adjust their degree of effort commensurate with the difficulty of the test they face. For example, Smith (1967) reported that students of high school age who were good readers adjusted their reading efforts

depending on whether they were reading for details or general impressions, whereas those who were poor readers used the same behaviors for both purposes. Similarly, Forrest and Waller (1981) asked third through sixth grade good and poor readers to read stories for four different purposes: (1) for fun, (2) to make up a title, (3) to find one specific piece of information as quickly as possible, and (4) to study. The older and better readers were more likely to expend additional effort on the more demanding tasks and to distribute effort to relevant parts of the text (skim appropriately). Interestingly, in light of the preceding discussion concerning the relation of non-verbal to verbal indices of monitoring, by fourth grade, the majority of children know how to skim for specific facts although they cannot describe how they do this until much later (Kobasigawa, Ransom, & Holland, in press). As they become more experienced text learners, children become better able to adjust their effort-allocation in an economical manner.

An excellent method of studying effort-allocation is the study-time apportionment task introduced by Masur, McIntyre and Flavell (1973). Grade school children were given lists of pictures to learn in a multi-trial free recall study. On each trial but the first, they were permitted to select half of the items for further study. By third grade, students selectively selected for extra study items they had missed on previous recall attempts. Even retarded children can be trained to use this strategy (Brown & Campione, 1977).

This strategy is not so simple, however, if one wants to apply it to the task of learning from texts. The learner must still select for extra study material she has failed to recall, but judging one's mastery of the

gist of texts is more difficult than judging verbatim recall of a list of items (Brown, Campione, & Barclay, 1979). While attempting to learn a text to mastery it is necessary to shift attention finely in tune with one's subjective impression that certain points are known well enough to risk a test and that others need extra study. In addition, one must estimate which segments of the material are important enough to warrant attention and which are trivial and can, therefore, be ignored. For example, the ideal strategy is to concentrate first on the most important elements of text and then, as these become well known, shift to lesser and lesser elements until a full representation of the text is built-up: as one's degree of learning improves, one must shift attention from a concentration on main points to an attempt to fill in the details.

Brown and her colleagues examined effort and attention allocation as an index of memory monitoring while studying texts (Brown, Smiley, & Lawton, 1978). Students from fifth through twelfth grade, together with college students, were asked to study prose passages until they could recall all the details in their own words. They were allowed repeated study trials. The passages were divided into constituent idea units rated in terms of their importance to the theme; there were four levels of rated importance. On each trial the students were allowed to select a subset (15%) of the idea units to keep with them while they attempted recall.

On the first trial, the majority of students at all ages selected the most important units to help them recall. Children below high school age continued to do this, even though they became perfectly able to recall the most important information without aid, but persistently failed to recall additional details. College students, however, modified their selection as

a function of their degree of learning: on the first trial they selected predominantly important (Level 4) units for retrieval aids. On the second trial they shifted to a preference for Level 3 units, whereas on the third trial they preferred Level 2 units. As they learned more and more of the material, college students shifted their attention-allocation to reflect their estimated state of knowledge.

Older high school students showed the same basic pattern as the college students but they were one trial behind; they did not begin to shift to less important units until the third trial. This lag could be due to slower learning, i.e., both groups shifted when they reached the same criterion of learning but the younger students took an extra trial to reach that criterion. It could also be due to a slower shift in attention-allocation, i.e., both groups learned as much on each trial but it took high school students longer to realize that they should adjust their attention. The latter appears to be the correct interpretation for, even when students were matched on the basis of degree of learning on each trial, the younger students still took longer to change their effort-allocation pattern in the face of their level of mastery.

The ability to fine-tune one's allocation of attention to reflect mastery level is a late developing skill, perhaps because it requires the coordination of various forms of knowledge. To allocate his attention in a manner responsive to his state of existing knowledge, the learner must have 1) information concerning the current state of knowledge, i.e., what he knows and what he does not yet know; 2) knowledge of the task demands of gist recall; 3) knowledge of the fine gradiation of importance of various elements of texts, i.e., what is important to know and what can be

disregarded; and 4) the strategic knowledge to adjust his allocation of effort in response to this information.

In short, the ability to monitor one's state of learning depends on the sensitivity one has to the factors in the tetrahedral model; strategy, knowledge, material, and task demands all influence the degree to which a child will be able to coordinate his plans and engage in active monitoring. Nonverbal indices of monitoring seem to be more reliable than verbal reports, although the exact relationship between the two deserves attention. Effort allocation as measured by reading speed (Baker, 1979; Capelli & Markman, 1980; Greeno & Noreen, 1974; Harris et al., 1981; Kieras, 1978) or attention deployment (Belmont & Butterfield, 1977; Bisanz, Vesonder, & Voss, 1978; Brown & Campione, 1977, 1978; Brown & Smiley, 1978; Brown, Smiley, & Lawton, 1978; Masur, McIntyre, & Flavell, 1973; Posnansky, 1978; Wellman, in press) seems to be a sensitive index of memory, learning, and comprehension monitoring that deserves further attention.

3. Self-Regulation. Any active learning process involves continuous adjustments and fine-tuning of action by means of self-regulating processes and "other even more mysterious" mechanisms (Marshall & Morton, 1978). Psychologists interested in mechanisms of growth and change have traditionally been concerned with such self-regulating processes. Of course, substantial contributions are made by external agents, which we will discuss in the next section. But even without external pressure, human thinkers "play" with thinking (Gardner, 1978), i.e., subject their own thought processes to examination and treat their own thinking as an object of thought. Similarly, learners regulate and refine their own actions, sometimes in response to feedback concerning errors, but often in

the absence of such feedback. Indeed, even if the system with which they are experimenting is adequate, active learners will improve upon their original production (Karmiloff-Smith, 1979a,b).

Recently, the term metacognition has been extended to encompass such regulatory functions as error-detection and correction (Brown & DeLoache, 1978; Clark, in press), but the historical roots of such concepts can be found in most of the major developmental theories. For example, Binet was fascinated by individual differences in his daughters' cognitive styles of self-regulation (Binet, 1890, 1903) and, following intensive study with both normal and retarded children, he selected autocriticism (Binet, 1909) as a central component of intelligence.

Given space limitations we will concentrate in this section primarily on relatively recent Genevan research on self-regulatory mechanisms in children's thinking and on the growing emphases in developmental psycholinguistics on error correction, systematization, and metalinguistic awareness.

Piaget's Theory of Regulation

In the latter part of his career, the transformational period (Riegel, 1975), Piaget became more and more interested in mechanisms of learning and the influence of both conscious and unconscious regulatory functions in promoting conceptual change. Again owing to space restrictions, we cannot begin to describe the complex theory of Piaget's latter years and the reader is referred to the excellent treatment by Gelman and Baillargéon (this volume). Briefly (and probably too simplistically), Piaget distinguished between three primary types of self-regulation: autonomous, active, and conscious.

Autonomous regulation is an inherent part of any "knowing act;" learners continually regulate their performance, fine-tuning and modulating actions, however small the learner and however simple the action (Bruner, 1973; Koslowski & Bruner, 1972). Active regulation is more akin to trial and error, where the learner is engaged in constructing and testing "theories-in-action" (Karmiloff-Smith & Inhelder, 1974/75). Under the guidance of a powerful theory-in-action the learner tests a current theory via concrete actions that produce tangible results. Not until a much later stage can the learner mentally construct and reflect upon the hypothetical situations that would confirm or refute a current theory without the need for active regulation. Conscious regulation involves the mental formulation of hypotheses capable of being tested via imaginary counterexamples or confirmatory evidence.

Consciousness first emerges as the child becomes capable of reflecting upon her own actions in the presence of the actual event. At this initial stage, consciousness is tied to concrete action but does not direct it. The child's "reactions remain elementary, the subject is likely to distort conceptualizations of what he observes, instead of recording it without modification." Such distortion can be quite dramatic. For example, having witnessed an event that is contrary to a tenaciously held belief, the "subject contests the unexpected evidence of his own eyes and thinks that he sees what he predicted would happen" (Piaget, 1976, p. 340).

At the most mature level, which Piaget would prefer to restrict to the stage of formal operations, the entire thinking process can be carried out on the mental plane. The learner can consciously invent, test, modify, and generalize theories and discuss these operations with others.

> Finally, at the third level (from eleven to twelve years) which is that of reflected abstraction (conscious products of reflexive abstraction) the situation is modified in that cognizance [consciousness] begins to be extended in a reflexion of the thought itself--This means that the subject has become capable of theorizing and no longer only of "concrete," although logically structured, reasoning. The reason for this is the child's new power of elaborating operations on operations--he thereby becomes capable of varying the factors in his experiments, of envisaging the various models that might explain a phenomenon, and of checking the latter through actual experimentation (Piaget, 1976, pp. 352-353).

In brief, the developmental progression is from unconscious autonomous regulation to active regulation but in the absence of anything more than a "fleeting consciousness." The beginning of conscious reflection occurs when the child is capable of considering her actions and describing them to others, albeit sometimes erroneously. The mature level of reflected abstraction, however, is characterized by conscious processes that can be carried out exclusively on the mental plane. Mature learners can create imaginary worlds, and theories to explain actions and reactions within them. Such theories can be confirmed or refuted by means of the further construction of mental tests, conflict trials, or thought experiments, that extend the limits of generality of the theory. This is the essence of scientific reasoning and the end state for a Piagetian development progression of "child as scientist."

The progress to conscious regulation of problem solving via thought experiments, hypothesis testing, and reflected abstraction is well illustrated in Anzai and Simon's (1979) microgenetic analysis of an adult who is systematically refining her procedures for solving a five disc Tower of Hanoi problem. Within a single session the subject progressed through three stages. First, she was totally concerned with the goal of completing the task by whatever means possible. In the intermediate stage, she became

theory-driven, seeking to understand the principles behind the task, guiding herself explicitly by mentioning intermediate goals, and pausing after each goal had been reached to plan for the next goal. Theories-in-action (Karmiloff-Smith & Inhelder, 1974/75) were being created and tested in this phase. In the third phase, the subject shows Piaget's "transcendance of action by conceptualization," that is "reflection directing action." Before undertaking to solve the puzzle again, the subject tested her understanding by reviewing the moves of the component one, two, three and four disc problems. In so doing, she explicitly stated the main principle of recursivity, and the essential notion of the transfer of pyramids of discs (Anzai & Simon, 1979).

The microgenetic learning route followed by this adult subject is recapitulated macrogenetically. Piaget collected protocols on children solving The Hanoi Tower (Piaget, 1976). In the early stage of solution, children complete a three-disc problem by trial-and-error, without being conscious of the principles. None of the younger subjects (five years old) made a plan, or were able to predict how they were going to move the tower (see, however, Klahr, 1978 for earlier evidence of planning on this task). After the fact, their justifications and explanations were noninformative. In an intermediate stage, correct solutions became stable for three-disc problems but were not readily transferred to more difficult problems. There was some evidence of planning ahead and the beginning of the ability to describe the procedures used during a successful attempt. The final stage (approximately eleven years of age) was characterized by rapid and stable success on three-disc problems and increasingly inferential anticipation of the rules for solving five-disc problems. Having completed

a four-disc problem, one child asked to predict how to solve a five-disc problem responded:

> "There's one more, you have to make more moves, otherwise it's the same system--you always take away the smaller one, then the middle one, then you put the small one on the middle one and you can get at the bigger one; that makes a small pyramid there, and then the way is clear to do it all again. I can start all over again; it's the same story afterward" (Piaget, 1976, p. 298).

By Piaget's stage III, the child's understanding of the principles of recursivity and the pyramid-subgoal strategy (Anzai & Simon, 1979) is not only fully articulated, but it directs the subsequent problem solving attempt. The entire procedure can be corrected, examined, and revised in thought, before it is attempted in action. This is the essence of conscious control of action, the hallmark of formal operations.

Metaprocedural Reorganization and Systematization

Piaget's colleagues, Inhelder and Karmiloff-Smith, have introduced another concept relevant to this discussion of self-regulation, that of metaprocedural reorganization (Karmiloff-Smith & Inhelder, 1974/75; Karmiloff-Smith, 1979a). The basic idea is that learning within a domain follows a predictable sequence that is characterized by internal pressure to systematize, consolidate, and generalize knowledge. The prototypical microgenetic sequence is that the child first works on developing an adequate partial theory for a salient aspect of the problem space: the partial theory is practiced and perfected until it is fully operational. Only when the partial theory is consolidated and functioning efficiently can the child step back and consider the system as a whole. Typically, the child will develop several juxtaposed theories adequate for various parts of the problem space, each theory operating in isolation from the other.

Once the procedures are functioning well, the next stage of development is possible and the child "steps-up" and reconsiders the problem-space metaprocedurally. Once children become aware of the discrepancies or contradictions resulting from the simultaneous existence of several different partial theories, they begin attempts to reconcile the differences and obviate contradictions resulting from the juxtaposition (Inhelder, Sinclair, & Bovet, 1974).

A concrete example might help to clarify this complicated theoretical notion. Karmiloff-Smith and Inhelder (1974/75) asked four- to nine-year-old children to balance rectangular wooden blocks on a narrow metal rod fixed to a larger piece of wood. Length blocks had their weight evenly distributed, and the correct solution was to balance them at the geometric center. Weight blocks had the weight of each "side" varied either conspicuously (by gluing a large square block to one end of the base rectangular block) or inconspicuously (by inserting a hidden weight into a cavity on one end of the rectangular block).

At first, the children made the blocks balance by brute trial and error using proprioceptive information to guide action. Behavior was purely directed at the goal of balancing. This ploy was obviously successful; the children balanced each block in turn. There was no attempt to examine the properties of the objects that led to balance and no attempt to subject each block to a test of a unifed theory.

This early errorless, but unanalyzed, phase was supplanted by the emergence of strong theories-in-action. These theories were directed at uncovering the rules governing balance in the miniature world of these particular blocks. Unfortunately, they were incomplete rules that produced

errors. A common early theory developed by the children was to concentrate exclusively on the geometric center and attempt to balance all blocks in this fashion. This works for unweighted blocks. When the theory did not result in balance, the blocks involved were discarded as exceptions ("impossible to balance").

After this theory was well established and working well for length blocks the child became discomforted by the number of, and regularity of, the errors. A new juxtaposed theory was then developed for the conspicuous weight blocks. For these, the children compensated for the weight that was obviously added to one end and adjusted the point of balance accordingly. For a time, however, length and weight were considered independently. Length blocks were solved by the geometric center rule and conspicuous weight blocks were solved by the rule of "estimate-weight-first and then compensate." Inconspicuous weight problems still generated errors; they looked identical to the unweighted blocks and were, therefore, subjected to the dominant geometric center rule. When they did not conform to the theory they were discarded as anomalies that were "impossible to balance." The children's verbal responses reflected these juxtaposed solutions, with exclusively length justifications given for unweighted blocks and weight justifications given for conspicuously weighted blocks.

Gradually and reluctantly, the children entered the period of metaprocedural reorganization which was only possible when both their juxtaposed procedures were working smoothly. Now, the young theorists were made uncomfortable by the remaining exceptions to their own rules and began to seek a rule for them. In so doing, a metaprocedural reorganization was induced that resulted in a single rule for all blocks. The children

abandoned the simple theories and reorganized the problem space so that a single unifying theory predominated. Now, the children paused before balancing any block and roughly assessed the point of balance. Verbal responses reflected their consideration of both length and weight, e.g., "You have to be careful, sometimes it's just as heavy on each side and so the middle is right, and sometimes it's heavier on one side." After inferring the probable point of balance, and only then, did the child place the block on the bar.

There are three main points to note about this example: first, there is the finding of a developmental lull or even a seemingly retrogressive stage when errors predominate. Initially, the children made no errors; all blocks were balanced. But, during the quest for a comprehensive theory of balance, the children generated partially adequate procedures that resulted in errors. Only when the unifying theory was discovered did the children revert to perfect performance. If errors alone formed the data base a U-shaped developmental growth curve would be apparent (Strauss & Stavey, in press). Actually, what was happening was that the children were analyzing the problem space to generate a theory that would incorporate all the blocks. In so doing they made what looked like errors but what were often tests of the existing partial theory.

A second main point is that metaprocedural reorganization leading to a "stepping-up" in theory complexity is only possible when the partially adequate, juxtaposed systems are well established (see also Siegler, 1981). It is essential that the child gain control of simple theories in her quest for a more complex and more adequate theory. Karmiloff-Smith and Inhelder refer to this as creative simplification.

> The construction of false theories or the overgeneralization of limited ones are in effect productive processes. Overgeneralization, a sometimes derogatory term, can be looked upon as the creative simplification of a problem by ignoring some of the complicating factors (such as weight in our study). This is implicit in the young child's behavior but could be intentional in the scientist's. Overgeneralization is not just a means to simplify but also to unify; it is then not surprising that the child and the scientist often refuse counterexamples since they complicate the unification process. However, to be capable of unifying positive examples implies that one is equally capable of attempting to find a unifying principle to cover counterexamples . . . [there is] a general tendency to construct a powerful, yet often inappropriate hypothesis which [learners] try to verify rather than refute. This temporarily blinds the [learner] to counterexamples which should actually suffice to have them reject their hypothesis immediately (Karmiloff-Smith & Inhelder, 1974/75, p. 209).

Progress comes only when the inadequate partial theory is well established and the learner is free to attempt to extend the theory to other phenomena. In this way the theorists, be they children or scientists, are able to discover new properties that in turn, make it possible for new theories to be constructed.

The third main point is that metaprocedural reorganization is not solely a response to external pressure or failure, but rather occurs spontaneously when the child has developed well functioning procedures that are incomplete but adequate for the task at hand. It is not failure that directs the change but success, success that the child wishes to extend throughout the system.

A similar U-shaped developmental pattern has been observed in children's language acquisition (Bowerman, in press; Karmiloff-Smith, 1979a). The phenomena under consideration are "errors" in children's spontaneous speech. The particular errors of interest are those that are preceded by a period of correct usage; these are hence referred to as "late errors" (Bowerman, in press). For example, consider the child's use of

plural (-s) and past tense (-ed) morphemes. The typical developmental progression is that children produce correct instances of plural and past tense forms of both the regular (dogs, cats, trees, or walked, jumped, climbed) and irregular (mice, feet, went, broke) kinds (Bowerman, in press). Next, the irregular pattern is replaced by an incorrect, overgeneralization of the regular form (foots, mouses, goed and breaked). Eventually the correct forms reappear.

The explanation for this U-shaped development is that the original correct usage was due to the child having learned the irregular (as well as regular) forms as individual cases. With repeated experience with the regular pattern, the child recognizes the systematicity involved, abstracts the general rule, and applies it too broadly to all plurals (hence, mouses) or all past tense forms (hence, goed and breaked). Errors occur where they had not previously. When the system is fully established, the child is ready to admit exceptions to the dominant rule and the irregular forms reappear; this time they are part of an integrated theory, however, being regarded as exceptions to the rule, not just isolated forms. (For many other examples, see Bowerman, in press, and Karmiloff-Smith, 1979a.)

Levels of Self-Regulation. In this brief and oversimplified synopsis of latter day Genevan psychology and language acquisition data, a central place in theoretical speculation is afforded to the concept of self-regulation; there is basic agreement that self-regulatory functions are integral to learning and are central mechanisms of growth and change. Similarly, in the emergent field of metacognition, the notion of self-regulatory mechanisms has a central place (Brown & DeLoache, 1978).

All agree that there are many degrees of self-regulation and that self-regulation is essential for any "knowing act." It is important to note, however, that a sharp distinction is made in both theories of language acquisition and in Genevan psychology, a sharp distinction that has not been made as clearly in the metacognitive literature. The distinction is between conscious awareness and direction of thought, versus self-correction and regulation that can proceed below this level.

Piaget (1976, 1978) distinguishes sharply between active regulation as part of any knowing act and conscious regulation and direction of thought, the keystone of formal operations. The first process is age independent, even the young learner succeeds in action by regulating, correcting, and refining his current theories. Some form of error correction must be part of any active learning attempt, even very young children are capable of regulating their activities by means of a systematic procedure of error detection and correction. For example, in a recent study, DeLoache, Sugarman, and Brown (1981) observed young children (24-42 months) as they attempted to assemble a set of nesting cups. Children in this age range did not differ in the likelihood of their attempting to correct a set of non-seriated cups. They did, however, differ in their strategies for correction.

The most primitive strategy, used frequently by children below 30 months, was brute force. When a large cup was placed on a smaller one, the children would press down hard on the non-fitting cup. Variants of brute pressure were twisting and banging, but the same principle held; the selected cup will fit if only one can press hard enough. Older children also used the brute force approach, but only after an unsuccessful series of maneuvers; for them it appeared to be a last resort.

A second strategy initiated by some of the younger subjects was that of trying an alternative. After placing two non-fitting cups together the child removed the top cup and did one of two things: He either looked for an alternative base for the non-fitting cup or he tried an alternative top for the original base. Both ploys involve minimal restructuring and necessitate considering the relation between only two cups at any one time. The third characteristic ploy of children below 30 months was to respond to a cup that would not fit into a partially completed set of cups by dismantling the entire set and starting again.

Older children (30-42 months) faced with a non-fitting cup engaged in strategies that involve consideration of the entire set of relations in the stack. For example, one sophisticated strategy was insertion; the children took apart the stack at a point that enabled them to insert the new cup in its correct position. A second strategy, reversal, was also shown by older children. After placing two non-fitting cups together, the child would immediately reverse the relation between them (5/4 immediately switched to 4/5).

The rapidly executed reversal strategy was not shown by the younger group. Some young children would repeatedly assemble, for example, cups 4-1, starting with 4 as a base and then inserting 3, 2 and 1. Then they encountered the largest cup, that is, 5 and attempted to insert it on top of the completed partial stack, pressing and twisting repeatedly. When brute force failed, they would dismantle the whole stack and start again. Similarly, having assembled 1, 2, 4, and 5 and then encountering 3, the younger children's only recourse was to begin again.

The DeLoache, Sugarman and Brown (1981) study of self-correction in young children is used as one example (see also Koslowski & Bruner, 1972) of the obvious fact that even very young children correct their errors while solving a problem. Of more interest is the demonstration that the child's error correction strategies provide us with a window through which to view the child's theories-in-action. The very processes used to correct errors reflect the level of understanding the child has of the problem space. Similarly, developmental psycholinguists have argued that production errors are very informative; "the tongue slips into patterns" (Nooteboom, 1969). Such errors reveal a great deal about the organization of the semantic knowledge of the speaker (Bowerman, in press; Clark, in press).

Important though these early regulatory actions may be, the distinction between theories-in-action and reflection should not be overlooked. Error correction during language production is integral to the processes of using language and is present no less in young children (Bowerman, in press; Clark, in press) than in adults (Fromkin, 1973; Nooteboom, 1969). Metalinguistic awareness, in contrast, is assumed to be a product of adolescent rather than childhood thinking. The ability to step back and consider one's own thought (or language) as itself an object of thought and, to go further, use the subsequent conceptualization to direct and redirect one's cognitive theories, is currently believed to be late developing.

Confused in the metacognitive literature, even lost in some versions of the concept, is this essential distinction between self-regulation during learning and knowledge of, or even mental experimentation with,

one's own thoughts. Whatever distinctions must be made to render metacognition a more malleable concept, this one is a fine candidate for inclusion in the list.

4. Other-Regulation. The last strand of metacognitive inquiry to be addressed is the notion of a transference from other-regulation to self-regulation. Important as the processes of self-regulation may be, a great deal of learning occurs in the presence of, and is fostered by, the activity of others. Supportive-others such as parents, teachers, peers, etc. guide a novice to mastery and there seems to be a systematic regularity in how this guidance works.

A great deal of the work conducted on other-regulation has taken place within the framework of Vygotsky's (1978) theory of internalization. Vygotsky argues that all psychological processes are initially social, shared between people, particularly between child and adult, and that the basic interpersonal nature of thought is transformed through experience to an intrapersonal process. Thus, for Vygotsky, the fundamental process of development is the gradual internalization and personalization of what was originally a social activity.

Social settings where the child interacts with experts in a problem solving domain are settings where a great deal of learning occurs. Indeed, some would argue that the majority of learning is shaped by social processes (Laboratory of Comparative Human Cognition, in press a,b; companion volume). A great deal of this learning involves the transfer of executive control from an expert to the child. Children first experience active problem solving procedures in the presence of others, then gradually come to perform these functions for themselves. This process of

"internalization" is gradual; first, the adult (parent, teacher, etc.) controls and guides the child's activity, but gradually the adult and the child come to share the problem solving functions, with the child taking initiative and the adult correcting and guiding when she falters. Finally, the adult cedes control to the child and functions primarily as a supportive and sympathetic audience (Brown & French, 1979; Brown & Ferrara, in press; Laboratory of Comparative Human Cognition, in press a,b; Wertsch, 1978). Again, we have selected illustrations that span a wide age and task range in order to demonstrate the generality of this pattern; the first involves mother-child dyads and the second teacher-pupil interactions.

At least in middle-class homes, one stable locus of mother-child interactions is picture-book "reading." Ninio and Bruner (1978) observed one mother-infant dyad longitudinally, starting when the child was only eight months old and terminating (unfortunately) when he was 18 months old. From the very beginning their interaction could best be described as a dialogue with the timing of the mother's and the child's behavior following an almost complete alternation pattern, strikingly similar to the turn-taking conventions observed in dialogue. In this dyad, the mother initially was very much in command, and any participation from the child was encouraged. Indeed, Ninio and Bruner point out that the mother accepted an astonishing variety of responses as acceptable turn-taking behavior, interpreting anything as having a "specific, intelligible content." The "imputation of intent and content" to the child's activities constitutes "an important mechanism by which the child is advanced to more adult-like communicative behavior" (Ninio & Bruner, 1978, p. 8).

A dramatic shift in responsibility, however, came when the child began to use labels by himself. The mother began to act as if she believed the child had uttered words rather than babble. The mother's "theory of the child" changed and so did her actions. At first she appeared to be content with any vocalization, but as soon as actual words could be produced the mother "stepped-up" her demands and asked for a label with the query "what's that?" The mother seemed to increase her level of expectation, first "coaxing the child to substitute a vocalization for a nonvocal sign and later a well-formed word for a babbled vocalization" (p. 12). Initially the mother did all the labeling because she assumed that the child could not, but later the mother started

> a cycle with a label ONLY if she thinks that the child will not label the picture himself, either because he does not yet know the correct word, or because he is not attentive enough to make the effort at labeling. If circumstances seem more favorable for labeling to occur, she will usually start the cycle with a "What's that?" question (Ninio & Bruner, 1978, p. 14).

Responsibility for labeling is transferred from the mother to the child in response to his increasing store of knowledge, finely monitored by the mother. During the course of the study, the mother constantly updated her inventory of the words the child had previously understood, and repeatedly attempted to make contact with his growing knowledge base. For example,

(1) You haven't seen one of those; that's a goose.
(2) You don't really know what those are, do you? They are mittens; wrong time of year for those.
(3) It's a dog; I know you know that one.
(4) We'll find you something you know very well.
(5) Come on, you've learned "bricks."

DeLoache (in preparation) repeated many of these observations in a cross-sectional study of mothers reading to their children. In this study,

the children ranged from 17-38 months. The mothers of the youngest children pointed to the objects and labelled them, sometimes providing some additional information. In the middle age group, the children were much more active. Their mothers asked them to point to and label objects and to provide other information about the picture. These children often spontaneously provided labels ("There's a horsie"), or asked the mothers for labels ("What's this?"). In the oldest group studied, more complex stories were introduced and the mothers again assumed control, but they did much more than simply point to and label objects. They talked about the relation among the objects in the picture, related them to the child's experience, and questioned the child about their outside experience (e.g., "That's right, that's a bee hive. Do you know what bees make? They make honey. They get nectar from flowers and use it to make honey, and then they put the honey in the bee hive."). When the child was quite advanced with respect to naming the objects and knowing something about them, the mother then used the situation and the material to provide the child with a great deal of background information only loosely related to the actual pictures. It is not simply that the amount of help changes as the child becomes more competent, but the quality of help is finely geared to the child's current level.

In both the Ninio and Bruner and DeLoache dyads, the mother is repeatedly seen functioning in the child's "region of sensitivity to instruction" (Wood & Middleton, 1975) or "zone of proximal development" (Vygotsky, 1978). As the child advances so does the level of collaboration demanded by the mother. The mother systematically shapes their joint experiences in such a way that the child will be drawn into taking more and

more responsibility for the dyad's work. In so doing, she not only provides an optimal learning environment, but also models appropriate comprehension-fostering activities; these crucial regulatory activities are thereby made overt and explicit.

Ideally, teachers function as just such mediators in the learning process, acting as promotors of self-regulation by nurturing the emergence of personal planning as they gradually cede their own direction. In schools, effective teachers are those who engage in continual prompts to get children to plan and monitor their own activities (Schallert & Kleiman, 1979) and model many forms of critical thinking for their students (Collins & Stevens, in press), processes that the students must internalize as part of their own problem solving activities if they are to develop effective skills of self-regulation (Brown, Palincsar, & Armbruster, in press).

In a recent study, Palincsar and Brown (1981) developed a training procedure based on this theory of the internalization of comprehension-fostering skills first experienced in social contexts. The basic situation was an interactive tutoring dyad, where seventh graders were receiving instruction aimed at improving their reading comprehension skills. The children were referred by their teachers because, although they were able to decode at grade level, they had severe comprehension problems. Over many sessions the tutor and the child engaged in an interactive learning game that involved taking turns in leading a dialogue concerning each segment of text. Both the tutor and the child would read a text segment, and then the dialogue leader would paraphrase the main idea, question any ambiguities, predict the possible questions that might be asked about that segment and hypothesize about the content of the remaining passage

segments. The dialogue leader would then ask the other a question on the segment. In the next segment the roles were reversed.

Initially, the tutor modeled these activities, and the child had great difficulty assuming the role of dialogue leader when his turn came. The tutor was forced to resort to constructing paraphrases and questions for the tutee to mimic. In this initial phase, the tutor was modeling effective comprehension fostering strategies, but the child was a relatively passive observer.

In the intermediate phase, the tutee became much more capable of playing his role as dialogue leader and by the end of ten sessions was providing paraphrases and questions of some sophistication. For example, in the initial sessions, 55% of questions produced by the tutees were judged to be non-questions or questions needing clarification, but by the end of the sessions only 4% of responses were so judged. At the beginning of the sessions, only 11% of the questions were aimed at main ideas. But, by the end of the sessions, 64% of all questions probed comprehension of salient gist. Similar progress was made in producing paraphrases of the main ideas of the text segment. At the beginning of the sessions, only 11% of summary statements captured main ideas whereas at the end 60% of summary statements were so classified. The comprehension monitoring activities of the tutees certainly improved, becoming more and more like those modeled by the tutor. With repeated interactive experiences, with the tutor and child mutually constructing a cohesive representation of the text, the tutees became able to employ these monitoring functions for themselves.

This improvement was revealed not just in the interactive sessions but also on privately read passages where the students were required to answer

comprehension questions on their own. In the laboratory, such tests of comprehension were given throughout the experiment. On these independent tests, performance improved from 10% to 85% correct. And in the classroom, the students moved from the seventh to the 40-70 percentile when compared with all other seventh graders in the school. Not only did the students learn to perform comprehension fostering activities in interaction with their tutor, they were also able to internalize these procedures as part of their own cognitive processes for reading. Through the intervention of a supportive, knowledgeable other, the child is led to the limits of his own understanding. The teacher does not, however, tell the child what to do· she enters into an interaction where the child and the teacher are mutually responsible for getting the task done. As the child adopts more of the essential skills initially undertaken by the adult, the adult relinquishes control. Transference of power is gradually and mutually agreed on.

Although the supportive other in the laboratory is usually an experimenter, these interactive learning experiences are intended to mimic real-life learning. Mothers (Wertsch, 1978, 1979), teachers (Schallert & Kleiman, 1979) and mastercraftsmen (Childs & Greenfield, 1980) all function as the supportive other, the agent of change responsible for structuring the child's environment in such a way that she will experience a judicious mix of compatible and conflicting experiences. The interrogative, regulatory role becomes internalized during the process, and the child becomes able to fulfill some of these functions for himself via self-regulation and self-interrogation.

Mature thinkers are those who provide conflict trials for themselves, practice thought experiments, question their own basic assumptions, provide

counterexamples to their own rules, etc. And, while a great deal of thinking and learning may remain a social activity (Laboratory of Comparative Human Cognition, in press a,b), through the process of internalization, mature reasoners become capable of providing the supportive other role for themselves. Under these systems of tutelage, the child learns not only how to get a particular task done independently, but also learns how to set about learning new problems. In other words, the child learns how to learn (Bransford et al., 1981; Brown, 1982, in press a; see also Section V).

C. Status of Metacognition as a Concept

In the preceding review, it is clear that metacognition is not only a monster of obscure parentage but also a many-headed monster at that. In this final section, we will make an attempt to estimate the current status of the offspring and list some of the problems we see with the current use of the term.

We would like to emphasize our belief that in many ways this status report is premature. Scientific theorizing, like any other, must pass through stages. Consider, as an example, the novice block balancers (Karmiloff-Smith & Inhelder, 1974/75) described earlier. Initially, they are merely goal oriented; they concentrate on getting the new theory to work. The next stage is to develop and refine juxtaposed subsystems so that they work fluently. Only when these subsystems are functioning efficiently can the theorist step back and consider the entire problem space and systematize or reorganize it into a cohesive whole.

The recent history of theory development in the realm of metacognition can be viewed in this light. In the early seventies, attracted by the lure of a new sounding concept, developmental psychologists engaged in demonstration studies to see how the new idea would work. These early studies were often ingenious and the wave of enthusiasm they provoked was justified.

The initial stage is now over and we believe that the current stage is, and should be, devoted to the task of developing workable theories and procedures for separate parts of the problem space. It is for this reason that we chose to look separately at the strands of inquiry that gave rise to the step-child, metacognition. Currently a great deal of systematic work is being undertaken that we hope will lead to fluently functioning subsystems that are juxtaposed, existing and developing side-by-side. But this is an essential stage of theory building. Later, perhaps, when the main subsystems are better understood, metaprocedural reorganization (Karmiloff-Smith, 1979a) may be possible and a full understanding of the domain, metacognition, will be attained.

Doubt remains, however, concerning whether the domain(s) covered by metacognition will be tractable enough for such a total systematization. If one takes the wide view, metacognition as currently used refers to understanding in a very broad sense. What we have on our hands is no simple problem space!

In a recent review, Wellman (in press) referred to metacognition as a fuzzy concept, as others have done before. Wellman, however, went on to discuss four features of the fuzzy concept.

> First, the concept encompasses an essential, central distinction. However, this distinction serves to anchor the concept not

> intentionally define it. Second, prototypic central instances of the concept are easily recognized. However, third, at the periphery agreement as to whether an activity is legitimately metacognitive breaks down; the definitional boundaries are truly fuzzy. Related to this, and fourth, different processes all of which partake of the original distinction may be related only loosely one to another. Thus the term metacognition or metamemory serves primarily to designate a complex of associated phenomena (Wellman, in press, p. 3-4).

This is nicely put and well illustrates the loose confederation of topics included under the blanket term, metacognition. Of some concern, however, is whether the associated phenomena are closely linked enough to warrant the use of a single family name, that is: are we talking about family resemblances within an ill-defined, natural or fuzzy category, or about many categories? Would we not be better off at this stage to abandon the global term and work at the level of subordinate concepts, which are themselves somewhat fuzzy?

One suggestion is that the use of the term could be limited to one of its original usages, knowledge about cognition, where that knowledge is stable and statable (Gleitman, in press). Process terms, such as planning ahead, monitoring, resource-allocation, self-questioning, self-directing, etc., would then be used alone without the addendum, metacognition. Thus, for clarity and communicative efficiency, a case could be made that the term metacognition should be pensioned-off, or at least severely restricted in its extensional reference. Let us hasten to add that this is not because the phenomena subsumed under the term are trivial but rather because issues of fundamental importance may be obscured by the current arguments surrounding things metacognitive; arguments that are obscured because the participants do not always make it clear which head of the beast they are attacking or defending.

This brings us back to the problems mentioned at the beginning of this section. At present it is difficult to answer critical questions about metacognition, such as: "Is it late developing?" "Is it general or domain specific?" "Is it conscious?" without pausing to ascertain which type of knowledge or process is in question. Although metacognition may turn out to be a fuzzy concept with indistinct boundaries, this degree of imprecision provides an insecure basis for scientific inquiry. By referring to the process/knowledge under discussion by its subordinate name, i.e., planning ahead, error-correction, hypothesis-testing, etc., many of the current controversies, but by no means all, would evaporate. At least, we would know where we have real problems and which problems are those of communication failures.

We end by emphasizing one of the real advances spurred by the interest in metacognition, i.e., the revived concern for mechanisms of change. This has always been the hidden agenda of developmental psychologists but, until recently, there have been surprisingly few attempts to study change directly. Many of the studies reviewed here depart from the typical cross-sectional age comparison approach, and this is because many of the studies that have been inspired by the metacognitive boom have involved microgenetic analyses of children learning-by-doing on their own, or learning to develop self-regulatory skills through the intervention of supportive others. We turn now to a more detailed consideration of training studies, another area that has been considerably influenced by the interest in metacognition.

V. Intervention Research

A. Introduction

In this section, we will concentrate on research that has involved some attempt to elevate the performance of groups of learners; the major issue concerns the ways in which cognitive developmental research and theory can inform these attempts. A more traditional title for this section might be "educational implications," although that title would not be inappropriate, we believe it suggests a unidirectional flow of information -- "basic" research leads to advances in understanding, which in turn enables increasingly sophisticated and powerful treatment of more "applied" problems; as we learn more about cognitive development, we are in a position to outline more effective instructional packages. This will in fact be the major emphasis here. However, we would argue strongly that the flow of information is bi-directional.

Intervention research itself represents one important way of attempting to build and evaluate cognitive theory. If we understand the cognitive processes and learning mechanisms involved in some domain and something about developmental differences, we should be in a strong position to teach someone to perform more effectively. The outcome of such training attempts allow us to evaluate the quality of our underlying theories of the domain, learning, and individual differences. Further, consideration of the way(s) in which intervention fails and must be supplemented or modified to effect improvement in performance provides not only information about shortcomings in the original guiding theories, but also positive suggestions about the way in which those theories need to be altered. In this view, intervention research serves both as a way of

providing converging evidence for a variety of theoretical formulations and as a tool for developing and refining those theories.

As we have described thus far, we have come quite a long way in our understanding of the factors and their interactions that comprise adequate performance in a variety of learning and comprehension situations. Compared with a decade or so ago, we have a better representation of expertise within a variety of domains, more detailed descriptions of the developmental path toward expertise, and a considerably more elaborated analysis of the ways in which the "typical" developmental trajectory can break down. Armed with this information, we are better able to specify some of the skills that need to be taught, as well as some of the ways in which they might be taught.

The majority of the studies we will describe fit into the broad category of intervention research. Within this category, it is possible to distinguish a number of different emphases, those aimed at changing the learner, those concerned with altering the learning materials, and those in which the essential approach is to modify the learning situation in general. As with many subdivisions, these approaches are not mutually exclusive; nonetheless, different studies and educational practices do rest primarily on one or another of these emphases. As a simple example of the difference, consider a group of students who are having difficulty in learning some material from a reading assignment. To circumvent the problem, we might attempt to teach them strategies for studying and comprehending texts (modify the learner). An alternative would be to design more readable, better formed narratives that would minimize the need for more powerful comprehension activities (modify the materials). Or the

teacher might do both. An additional choice she has is to inform, or not to inform, the students of her purposes.

In our review, we will be concerned with three classes of questions: 1) What to teach; that 2) How to teach it: that 3) How to adapt what and how to individual differences, i.e., who is being taught. Note that (1) requires a theory of the components of academic performance, both within and across academic disciplines; that (2) requires a theory of learning: and that (3) requires theories of developmental and comparative differences -- how do students of varying ages differ; and within age, how do good and poor performers differ. Although a complete theory does not as yet exist, we argue that the data available constrain those theories sufficiently so that it is possible to derive some important conclusions.

To begin with, we will center our discussion on the issue of what should be taught, and return to the how and who later. One way of providing a context for this topic is to assume, as Rohwer did in the 1970 Handbook, that on the most general level, the aims of education are: 1) teaching the content knowledge, both declarative and procedural, sufficient for expertise within some academic domain; and 2) teaching learning to learn, i.e., enabling students to proceed more efficiently and independently.

Although these aims might be regarded as complementary, it may be more accurate to say that they are somewhat antagonistic in practice. Teachers frequently regard the amount of time they have to teach a particular course as insufficient for that purpose. If a large amount of time is devoted to teaching learning skills, that of necessity reduces the amount of time available for transmitting course content. And it is course content on which the students (and teachers) are generally evaluated.

A fairly clear example of the conflict can be seen in debates regarding various types of teaching formats. For example, the use of Socratic dialogue as a teaching approach embodies the modeling of many important learning activities, such as self-questioning, seeking relations, probing for further examples and counterexamples, etc. (Collins & Stevens, in press). In this way, it would seem to represent a promising vehicle for teaching students how to learn. Its less than universal acceptance, however, can be attributed in part to the fact that the rate at which specific content is transmitted is relatively low (Collins & Stevens, in press). Although students may be learning to learn, they are not necessarily learning much geography or history or math or... This learning process - learning product tension has been expressed succinctly by one well-known educator in discussing the "revolution in mathematics teaching known as the 'new math.'" He noted that the emphasis of the "new math" was on knowing and understanding what you were doing "rather than getting the right answer" (Lehrer, 1965).

From our perspective, the emphases of educational practice and cognitive developmental research have been somewhat different, and for good reasons. The main target of school programs has been the goal of teaching content knowledge; the preferred criterion measures have been performance on knowledge-based examinations. Students do well in school to the extent that they perform well on achievement tests in various subject areas. Given this criterion measure, it should not be surprising that the main goal is to somehow instill a powerful, well-organized knowledge base. But achievement tests provide only indirect measures of learning ability. If students were tested for the efficiency of their learning, there would be a

greater likelihood that learning processes would be a part of the school curriculum; that is, there is a tendency for teachers to "teach to the test," or more positively stated, they take the criterion task into account in designing their instruction. If learning skills were to be evaluated, they would be more likely to be taught. We do not wish to leave the impression that it would be an easy task to evaluate learning skills. Those who would undertake the task of developing a theory-based assessment instrument of learning would have to confront most of the thorniest problems in cognitive development. A central subset of the issues would include: Do learning skills as such exist? If so, what are they? How might they be assessed in such a way as to minimize the influence of specific knowledge? These are in fact some of the questions that have recently been attracting the attention of investigators interested in instructional research (Chipman, Segal, & Glaser, in press).

In contrast to the knowledge emphasis in schools, the major target in the developmental research literature has been on procedures for learning, or more recently on learning to learn. As an example of the difference between the two areas, we might say that a target of a geography curriculum would be to have the students know what the 50 states and their capitals are. More typical research questions would concern the specific strategies different children would use to set about the task of learning the information. There would also be concern with a specification of the factors underlying any developmental differences in the approaches adopted. More recently, this research on the role of specific strategies has been supplemented by a renewed interest in identifying more general "content-free" activities such as the metacognitive skills discussed in depth in Section IV.

This emphasis on learning activities in the research literature represents both a strength and a weakness. On the positive side, the work has documented the centrality of such activities to learning, and has shown that their inclusion in training programs can have important consequences. One weakness of this emphasis on learning activities, both specific and general, is that we know less about the development of extensive knowledge bases and the overall effects of increases in domain-specific knowledge (see Section III.B). In this regard, the recent work on knowledge factors is welcome. This relative lack is also not surprising; the acquisition of a well-articulated knowledge base in a semantically rich domain takes a considerable amount of time (Simon, 1979). Ideally, what we would like to be able to do is track the development of a knowledge base in some domain in a sample of students differing in age and ability. We would then be in a position to ask what the specific and general effects of incrementing knowledge are in students who differ in their experience with, and success in, school learning tasks. This would involve extensive longitudinal analysis of relatively few subjects, i.e., a case study methodology (Campione et al., in press). As we argued earlier, the use of microgenetic investigations is already contributing substantially to our understanding of learning mechanisms.

Having characterized educational practice as emphasizing knowledge rather than learning factors, we can also speculate on why this might be the case. First, note that we believe the difference is one of emphasis. We do not wish to argue that educators are not concerned with teaching students to learn. Instead, our point is that general learning activities, or cognitive skills (cf. Chipman, Segal, & Glaser, in press), tend not to

be taught directly. By directly, we mean an explicit attempt on the part of teachers to transmit the skills. This in turn could be because the lack of such instruction is defensible or appropriate; this view does have its proponents. Reasons for not teaching general cognitive skills include: 1) they do not exist; 2) if they do, they are a consequence of a well-developed knowledge base; or 3) if they do exist, they are acquired incidentally as a result of the modeling that is an integral part of instruction, and hence do not need to be taught explicitly.

The first point is straightforward. Schools may not teach general thinking skills because such skills do not exist. The second is also popular; all skills are heavily context-dependent and thus are an inherent part of the knowledge base of any semantically rich domain. This specificity-generality issue is one of the oldest debates going, and has been a central issue at a number of recent conferences on thinking and problem-solving skills (e.g., Chipman et al., in press; Tuma & Reif, 1979). For example, in his role as the concluding speaker at the Carnegie-Mellon conference on Problem Solving and Education, Newell noted that "...if there is one dichotomy that permeated this conference, it concerned the basic nature of problem solving. Specifically the poles are

Domain independence of Problem-Solving

vs.

Domain-specificity of Problem-Solving

The dichotomy is an old one." (Newell, 1979, p. 184).

Thus, one important set of research questions deals with the existence and identification of any general learning skills. For example, on the one hand, Goldstein (1979) asserts that "...the fundmental problem of

understanding intelligence is not the identification of a few powerful techniques, but rather the question of how to represent large amounts of knowledge in a fashion that permits their effective use." On the other hand, Simon (1979) argues that "...bare facts, however they are stored in memory, do not solve problems." The weight of the current evidence is that some fairly general skills have been identified and that their acquisition is essential for efficient learning. For example, Simon argues that is

> The evidence from close examination of AI programs that perform professional-level tasks, and the psychological evidence from human transfer experiments, indicate both that powerful general methods do exist and that they can be taught in such a way that they are relevant. (Simon, 1979, p. 86)

Similarly Brown, Collins and Harris (1978) argue that:

> We have come to see some surprising similarities in the kind of strategies and knowledge used in these different domains (story comprehension, solutions to mathematical problems and eletronic circuits). This suggests that there may be general learning strategies that will enhance a student's comprehension over a wide range of content areas. Rigly (1976) has claimed that 'the approach to teaching students cognitive strategies has been through content-based instruction and maybe this is wrong and should be reversed; that is content-independent instruction. (Brown, Collins & Harris, 1978).

In summary, we have argued that schools have emphasized the acquisition of domain-specific knowledge bases, whereas cognitive developmental researchers have centered their more recent efforts on the development of learning skills, both "specific" (e.g., rehearsal strategies) and "general" (e.g., performance monitoring). This emphasis on knowledge development could be justified in several ways: a) if there were no general learning skills, or b) if learning skills, general or specific, emerge without being explicitly taught. Relevant research questions then concern the existence of general skills, the extent to which they result automatically from a developing knowledge base, and the extent to which

they are acquired incidentally through modeling in specific content areas. Although the evidence is far from overwhelming, we argue that there are general, but weak (Newell, 1979), skills and that in many cases they do need to be taught explicitly. This view is coming to be adopted more frequently by educators (cf. Chipman et al., in press), particularly, although by no means only by those concerned with poorer learners.

Schools have emphasized the knowledge aspect of the tetrahedral model and researchers the activities component. Over the last decade, the two groups have come to the realization that both knowledge factors and learning activities along with their interaction need to be considered. In the next sections, we will argue that developmental research has much to say about ways in which educational programs might be modified, and that some of the implications we can draw are, in fact, being implemented.

B. Intervention Studies in Developmental Research: Early Trends

A notable feature of the last decade has been an increase in the number of studies aimed at the instruction of simple learning or remembering activities. An intervention methodology has become increasingly prominent, and investigators have asked a wide variety of questions about the way(s) in which performance in a number of domains can be improved. The vast majority of studies in the sixties and seventies were entirely theoretically motivated. In fact, the training study has historically been one of the favorite tools in the repertoire of the developmental psychologist, because it lends itself well to the analysis of a number of central issues (see Section II). It represents a vehicle for investigating key factors involved in learning and development. For example, one way of studying change is to attempt to engineer it. Hence,

interest in theories of change can lead fairly naturally to the use of intervention research (Brown, 1982).

Although the use of training studies is popular, their interpretation is not a simple matter. A great deal has been written about both the importance of training studies in comparative and developmental research and their underlying rationale. Athough we will touch on some of those issues later, we do not have the space available to go into any detail. In depth discussions of the various strengths and weaknesses of this approach to theory construction can be found in Belmont and Butterfield (1977), Brown and Campione (1978, 1981), Butterfield, Siladi, and Belmont (1980), and Campione, Brown, and Ferrara (in press).

Over the course of the decade, the type of instructional study has changed as researchers have begun to pay more attention to educational issues. These changes have stemmed from two, not independent, causes. One is that a number of psychologists have become more interested in questions of potential educational significance and have expended more of their efforts on understanding the components of performance in more typical academic pursuits, such as math and reading. At the same time, this decade has seen a steady increase in our knowledge about cognitive development and individual differences. As the emergent data and theories provided more detailed insights into a number of pertinent issues, developmental psychologists were better able to address educational issues. We would argue that it was these advances in our understanding that encouraged many to undertake instructional research.

Here we will trace some of the changes that have occurred in the learning strategies training literature (see Flavell, 1970b and see also

Gelman & Baillargéon, this volume, for a review of the Piagetian training studies). Brown, Campione and Day (1981) have classified training studies into three broad categories: blind, informed, and self-control. They differ in terms of when they were conducted historically, the nature of the interaction between the subject and the experimenter, the reasons for undertaking the research, and the criterion against which the outcomes were evaluated.

1. Blind training studies. These studies were historically the first in the sequence we will describe. The term "blind" was not intended to be perjuratative. These studies are termed "blind" because they tended to leave the subject in the dark about the importance of the activities they were being induced to use. The studies were by no means blind from the perspective of the experimenter. The choice of the activities to be trained was based on a well-articulated and insightful analysis of the demands of a number of memory or problem-solving situations, and the studies' main purpose was to evaluate hypotheses regarding both the processes involved in efficient performance on some tasks as well as the sources of developmental or comparative differences on those tasks. In this regard, they were extrememly successful; one impressive feature of a number of these studies was the finding that large improvements in performance could be engineered. It was this fact that encouraged those interested in educational issues to expend more effort on instructional research aimed at improving subjects' use of learning activities. In summary, these studies were designed for theoretical reasons, and were not addressed to educational issues, in contrast to some of the later studies we will describe. They were, however, directly responsible for the ensuing research.

A prototypical study might begin with the hypotheses that: 1) efficient performance requires the use of some task-appropriate strategy or learning activity; and 2) differences between individuals, or groups of individuals, reflect variations in the spontaneous use of such activities. If those hypotheses were correct, the question of why the less efficient were less likely to exploit such activities was addressed. Were the differences due to a failure to engage a usable activity such as rehearsal (production deficiency), or an inability to profit from the activity (mediation deficiency)? To address these questions, a training study might be conducted to induce the younger subjects to rehearse. If performance improved significantly and approached the level of older subjects, support for three propositions would be inferred: (1) rehearsal is an important component of task performance; otherwise, training its use should not help; (2) developmental differences are in part due to differential rehearsal, because inducing the younger children to use it did reduce the performance difference; and (3) the deficiency operating prior to training was one of production, not mediation. Very simple training studies provide data relevant to a number of important developmental issues, although their interpretation is not unequivocal (Campione, in press a).

The typical procedure in blind training studies is that children are instructed or induced to perform particular processing routines but are not helped to understand the significance of such activities. They are told what to do or are led to do it but they are not informed why they should act this way, or that it helps performance, or that it is an activity appropriate to a particular class of situations, materials, goals, etc. Although for some children this is sufficient in that they can infer the significance of the activity for themselves, for many this is not so.

As one illustration, consider tasks involving free recall of categorizable materials. Children can be induced to categorize through the use of clever incidental orienting instructions (Murphy & Brown, 1975), the material can be blocked into categories (Gerjuoy & Spitz, 1966), or recall can be cued by category names (Green, 1974). None of these procedures guarantee that the child understands why or even if recall is improved. But, all these methods are extremely successful in improving children's performance on a particular set of materials.

Similarly, in the area of paired-associates learning, subjects can be instructed to generate either verbal or imaginal elaborations involving the to-be-associated items (e.g., Rohwer, 1973): or the experimenter can engage the subjects in an activity that results in such elaborations (e.g., Turnure, Buium, & Thurlow, 1976). Alternatively, the pairs of items can be introduced in an already "elaborated" form, either verbal or visual. They can be presented in a sentence frame or in a scene involving some interaction between them (Reese, 1977). Any of these methods can speed learning.

The sheer frequency and, on occasion, magnitude of intervention effects caught the attention of those interested in remediation. Although there are numerous examples, we will mention only two here. One involves elaboration and the other rehearsal. In an experiment by Turnure, Buium and Thurlow (1976), educable retarded children (IQ's around 70) and normal children matched for CA (about seven years) were given a 21-item paired-associates list to learn. There was one study trial followed by a single test trial. In the labeling condition, subjects simply repeated the names of the items (e.g., soap-jacket) after the tester. In three other

conditions, the subjects were required to answer "what" or "why" questions about the pair, e.g., "What is the soap doing under the jacket?," "Why is the soap hiding in the jacket?," etc. The aim of these procedures was to lead the subjects to think about the meaning of the individual items and to force them to generate elaborations involving possible relations between the members of each pair.

The differences among the conditions were dramatic. The children in the labeling condition averaged 2.0 items correct, whereas those in the "what" and "why" groups were correct on an average of 14.4 items, an increase in recall of over 600%. This finding was true of both the retarded and nonretarded children; normal children of this age have not yet begun to use these kinds of elaborative strategies spontaneously (cf. Reese, 1977; Rohwer, 1973); as a result, they performed poorly unless given the questioning procedures during study, in which case they also improved dramatically.

The rehearsal study we will describe represents a much more intensive attempt to improve the short-term memory performance of retarded children: the goal was to bring them to the level of untrained college students. It is an important study both for the magnitude of the effects it produced and because the study addressed a number of additional theoretical points. Butterfield, Wambold and Belmont (1973) employed a standard probed short-term memory paradigm in which subjects were shown a series of six items and then asked to indicate the position in which a randomly selected one had appeared. They used a subject-paced procedure in which the participants pressed a button to view each successive item; thus, the subject was allowed to pause as long as she wished at any point in the series. College

students deal with tasks of this type through the use of rehearsal strategies. A typical strategy (Belmont & Butterfield, 1971) would involve studying the first three items as a set (i.e., pausing for an extended period following exposure of the third item), and then inspecting the last three items quickly (a "3-3 active passive" strategy). Retarded adolescents, like normal children below ten years of age, showed no evidence of the use of rehearsal strategies and performed poorly -- they were correct on approximately 35% of the trials.

They were then programmed to use the "3-3" strategy adopted by adults. The subjects were told to view the first three items and then to pause and repeat them as a set a number of times. After this, they were to expose and view the last three items quickly. This strategy raised the level of performance for the first three letters in the sequence, but recall of the last items was surprisingly poor. Butterfield et al. hypothesized that although the subjects were using the rehearsal strategy, they were not using an appropriate retrieval strategy. The most effective retrieval strategy would have two parts. First, when the probe item was presented the last three items would be "searched," taking advantage of the fact that these items would not yet have faded from memory. Second, if the letter were not among the last three, the rehearsed items would then be searched. An alternative approach, that of searching the initial rehearsed set first, would result in the subjects' "converting" the task to one of serial recall, a task for which the "3-3" study strategy would be inappropriate. The fact that after initial training retarded adolescents performed relatively well on the initial set of three items, together with some subsequent analyses of latency data, indicated that this "conversion" did

take place, thus impairing performance. This result emphasizes the interactive nature of the various components of performance in a given task. The study strategy is effective only if coupled with a compatible retrieval plan. In this case, the instructional design problem was complicated by the fact that the students were setting themselves a criterion task that was different from the one assumed by the experimenter.

These considerations led to a revised training procedure aimed at both the acquisition and retrieval component. The subjects were initially taught the acquisition strategy. They were then informed about, and led through, the correct retrieval plan. Finally, they were given explicit instruction in the coordination of the two. In the most detailed condition, the subjects achieved an accuracy level of around 85%, some 140% above their initial level and comparable to that of nonretarded adolescents given some, but not so detailed, training. It is important to note that the provision of the components of the overall plan was not sufficient to result in their effective use. Butterfield et al. also had to include explicit instruction in their sequencing and coordination. This is one of the earliest training studies in which the importance of executive functioning was emphasized. Butterfield et al. conclude from the series of studies that:

> We can now elaborate two deficiencies in addition to the lack of rehearsal that hold retarded subjects so far below their capacity. They do not properly sequence rehearsal and non-rehearsal learning techniques, and they neither intercoordinate multiple retrieval strategies nor coordinate these retrieval strategies with strategies of acquisition (1973, p. 667)

and

> If this failure of executive control is transsituational, and we assume that it is, then the appropriate level of analysis for future research is the level of selecting, sequencing, and

> coordinating processes that are in the cognitive repertoire. Trying to train executive function instead of the particular skills for whose success it must ultimately be responsible may save much effort and yield more general theory in the bargain (1973, p. 668).

Inducing subjects to employ task-appropriate activities can result in dramatic improvements in their performance. This can be done by teaching them the routines necessary (Butterfield et al., 1973), augmenting the original learning situation (Turnure et al., 1976), or by modifying the learning materials (Reese, 1977; Spitz, 1966). (As we will see, the same findings obtain when the goals are comprehension of text.) Although direct comparisons are impossible, it also appears that altering the learning activities of the learner has a larger effect than restructuring the materials (Butterfield & Belmont, 1977). What particularly caught the attention of those interested in education was the impressive magnitude of the effects achievable through direct instruction of learning activities.

The implications of this work are clear. If the goal is to enhance the learning and retention of specific (although presumably limited) sets of information, there are ways of engineering that learning. We have come to know a great deal about some of the activities that result in rapid learning and durable memory, and intervention studies have shown that getting young or poor learners to carry out some of those activities does result in greatly enhanced performance. It does not matter much whether the learner knows why or even what is being done. This is not trivial, as in many cases the learning of specific packets of information is either a goal in itself or necessary for further learning.

There are, of course, also limitations to these conclusions. The first problem is that there are clear limits on the extent to which

restructured learning environments can be expected to lead to positive effects. What can be learned depends upon the initial knowledge or capabilities of the performer. The learner's entering knowledge can determine if a particular intervention will be successful. 'An extremely simple case of instruction is to provide for learners examples from which a rule can be inferred. An example of this approach and of a knowledge x instruction interaction can be found in a number of experiments involving the balance beam problem reported by Siegler (1976, 1978). Subjects are shown a series of weight arrangements and asked to predict whether the beam will balance, or whether one side or the other will fall if support is withdrawn. Siegler has analyzed the problem in terms of a number of increasingly complex rules that represent progressive changes toward a full understanding of the principles involved. Rule I in Siegler's taxonomy is based on a consideration of weight factors only. If the amount of weight on either side of the fulcrum is the same, the scale will balance: otherwise, the side with more weight will drop.

Siegler (1978) worked with groups of three- and four-year-olds who had not yet acquired this rule. Their predictions were essentially random. Interested in how his subjects might acquire Rule I, Siegler administered a series of feedback trials. The subjects would predict what would happen to the beam when supports holding it in place were removed, then the supports were withdrawn and the subjects were allowed to observe what actually happened. The process of formulating hypotheses, obtaining data, and then re-evaluating those hypotheses could be said to be being simulated. The main result was that the four-year-olds tended to learn, or more specifically to acquire Rule I, whereas the three-year-olds did not.

Subsequent experiments showed that four-year-olds, although random responders on prediction trials prior to any feedback did encode, or attend to (Zeaman & House, 1963) the relevant weight dimension, whereas three-year-olds did not. In some sense, the four-year-olds may be said to know more about the balance problems, i.e., that weight is a relevant dimension, than the three-year-olds, and that this knowledge is necessary for the intervention to produce learning. In fact, three-year-olds taught to encode weight and then given the feedback trial showed an increase tendency to acquire Rule I.

In this situation, we would like to emphasize the developmental pattern obtained. The performance of the three- and four-year-olds did not differ significantly prior to the presentation of the feedback series (they were both random). However, after the treatment, the groups did differ significantly. This "divergent effect," in which intervention results in increasing the difference between younger and older children, is a far from uncommon finding; in fact, as we will emphasize later, it is quite typical in some classes of instructional studies. This effect stems from the fact that the instruction afforded requires some underlying competency for it to be effective. Older children tend to exploit that competency and profit from instruction, whereas younger children do not; thus, the instruction is less effective.

A second problem is that blind training techniques can, and often do, help people learn a <u>particular</u> set of materials, but existing data suggest that they do not necessarily help people change their general approach to the problem of learning new sets of materials. In short, these procedures fail to result in maintenance (durability) and generalization (transfer) of

the learning strategies (Brown & Campione, 1978; Campione & Brown, 1977). Children neither perform these activities subsequently on their own volition nor transfer them to new but similar learning situations. Something other than "blind training," therefore, seems to be necessary to help many children learn on their own.

In summary, blind training studies demonstrated powerful effects following training or the inducing of appropriate activities during the acquisition and retrieval of to-be-learned material. One immediate implication of these studies is that it is possible to design instructional interventions to facilitate the mastery of specific bits of information. These implications are limited by a number of other considerations. One is that simply simulating the desired activities does not result in facilitation for all learners in all situations (i.e., the activities x subject characteristics or activities x knowledge interactions inherent in the tetrahedral model). Another is that although such interventions may lead to mastery of specific materials, they may not lead to transfer (the activities x criterial task interaction).

The transfer issue, or the learning vs. learning to learn distinction, can be seen in many school situations. For example, consider the case of a teacher providing the acronym HOMES to students in an attempt to help them learn the names of the Great Lakes. This is a very reasonable thing to do, and it does work. If the goal is learning the lake names, nothing else is of much import. If, however, the teacher also wants the students to come to use this mnemonic/retrieval activity to help them learn other sets of arbitrary material, the problem would be an entirely different one; and the subjects' ability to generate those activities appropriately on new occasions would be the target of instruction.

This distinction maps nicely onto the state of affairs in the early seventies. Brief instruction could result in impressive improvements in task-specific performance, but transfer following that intervention was exceedingly limited. The strongest statement that could be made was that extending the amount of training seemed sufficient to produce greater maintenance (e.g., Borkowski & Wanschura, 1974); but generalized effects of instruction were more difficult to bring about (Brown, 1974; Campione & Brown, 1977). But it was necessary to first identify appropriate learning activities and show that teaching them to young or poor learners would result in enhanced performance before it would make any sense to consider transfer issues. Transfer of non-helpful activities would not be of much interest. It was the successes obtained in the early training studies that led to more intensive research on factors involved in transfer.

As investigators shifted their criterial task, seeking transfer rather than only task-specific improvement, they also searched for suggestions about how to go about modifying instruction. Providing the requisite learning activities to immature learners did not seem sufficient to lead to flexible access to those routines. To redesign instruction, it would be necessary to know what other skills or activities would have to be taught to improve access. It was around this time that some of Flavell's early work on metamemory began to appear (e.g., Flavell, 1971a; Flavell, Friedrichs, & Hoyt, 1970; Masur, McIntyre, & Flavell, 1973). In an insightful series of studies, Flavell and his colleagues demonstrated that younger children tended not to know as much about their memory system as older children and did not appear as capable as older children of regulating and monitoring that system. Similarly, mildly retarded children

also appeared to demonstrate particular problems in these areas (Brown, 1974, 1978). One global statement of the overall pattern of results is that young children and poor learners, those who were the targets of the blind training studies, did not seem to know much about the memory system that the trainers were attempting to modify, nor were they particularly capable of overseeing the resources that instructors provided for them.

It is interesting to note that Flavell's early interest in metacognitive factors arose in the context of production deficiencies. Brief training was sufficient to induce the use of a number of memory-enhancing activities, and one question which was raised by this finding was why the subjects failed to employ those activities spontaneously. Even more provocative were those cases (e.g., Keeney et al., 1966; Brown, Campione, & Barclay, 1979) where subjects, for example, rehearsed when told to do so and performed significantly better; when prompting to rehearse was withdrawn, rehearsal was abandoned, and performance returned to baseline levels. These data could be explained if the subjects did not know why rehearsal was helpful or even that it was helpful, that is, if the subjects did not understand the significance of the activities. And the metamemory data seemed to support these notions.

In this context, the failure to find transfer of instructed routines could be assumed to result from an incomplete "treatment" of the initial problem(s) responsible for the strategy deficits. At this point, research aimed at assessing the effects of inducing metacognitive supplements to strategy training was undertaken. As a rough distinction, we can consider two types of experiments, those involving informed training and those involving self-control training (Brown et al., 1981). Generally subjects

in informed training studies are given some additional information about the strategy they have been instructed to use; and those in self-control studies are also given explicit instruction about overseeing, monitoring, or regulating the strategies (Campione, in press a,b).

2. Informed Training. Brown, Campione and Day (1981) refer to intermediate levels of instruction as informed training. Here, children are not only prompted to perform particular activities, but they are also provided with information about the significance of these activities. As one example, Kennedy and Miller (1976) were able to show that an instructed rehearsal strategy was more likely to be maintained in the absence of experimenter prompts if it had been made clear to the subject that the use of the strategy did result in improved recall. This effect can be obtained with a variety of strategies and subject populations. For example, a similar result with retarded children was obtained by Kendall, Borkowski and Cavanaugh (1980) in work centering on the use of elaborative strategies to hasten paired-associates learning. Somewhat more elaborate instructional packages have been investigated by other authors, including Burger, Blackman, Holmes, and Zetlin (1978) with retarded children and Ringel and Springer (1980) with children in regular classes. The hallmark of these studies was the inclusion, during and following training, of much more detailed information about the need for, and effects of, the instructed routines. Again, the result of these extended instructions was to lead to enhanced transfer. For example, in the Burger et al. study the subjects, who were taught to use a categorization plan to facilitate free recall, continued three weeks after training to show significant superiority over an untrained control group with regard to both clustering and amount recalled.

One can also inform subjects indirectly of some aspects of strategy use. To demonstrate the transituational nature of a strategy, one can train the use of a particular routine in multiple contexts (Brown, 1978). For example, Belmont, Butterfield and Borkowski (1978) compared groups of subjects who had received rehearsal training in one vs. two contexts. The two contexts differed slightly in their response requirements, thereby demanding that the rehearsal strategy be varied accordingly to take this into account. The two context group was more likely to show transfer to a third context. This is, of course, not a new finding; precedents can be found in the discrimination learning literature (e.g., Johnson & Zara, 1960; Sherman & Strunk, 1964). In that literature can also be found evidence that, on some occasions, multiple training is effective only if appropriate exemplars are found (e.g., Beaty & Weir, 1966).

Another relevant finding is that the tendency to maintain a strategy seems to be a function of the efficiency and precision with which the strategy was carried out during training (Borkowski, Cavanaugh, & Reichart, 1978; Butterfield & Belmont, 1977). Students who execute a strategy well at the time of training are more likely to maintain that strategy subsequently. For example, Paris, Newman and McVey (in press) looked at the process of strategy acquisition in a study that included a number of the features of informed training. After two days of baseline performance on free recall of categorized lists, Paris et al. divided their seven- and eight-year-old subjects into two training groups. In one, the non-elaboration (blind in our terminology) group, the subjects were told how to carry out some mnemonic activities: grouping, labeling, cumulative rehearsal, and recalling by groups. The second, or elaboration (informed)

group, was in addition given a brief rationale for each of the different behaviors; they were also provided feedback about their performance after recall. The elaboration group outperformed the non-elaboration group on both the training session and on subsequent maintenance probes. In this study, information was provided prior to training, and the effect was to augment the immediate effects of training. Furthermore, as in the other informed studies, there was a longer-term effect; i.e., increased maintenance.

Elaborated training resulted in better "acquisition" performance. Subjects so trained carried out the strategies more frequently and effectively and were also the ones who showed greater maintenance. We might generalize a bit and propose that any procedure that leads to efficient strategy execution during training will result in maintenance. One suggestion from these data is that to facilitate transfer subjects need to be run to some criterion of mastery during acquisition.

Paris et al. (in press) prefer another explanation and offer some data in support. They argue that provision of information about the rationale underlying each component activity leads subjects to understand the significance of those activities, i.e., they become aware of the strategies' benefits; and that this awareness is, in part, responsible for continued unprompted use. To evaluate this possibility, they obtained metacognitive judgments throughout the course of the experiment. In fact, the subjects in the elaborated training condition did show increased awareness of the role of sorting activities compared with those in the nonelaborated condition. Also, awareness scores were significantly correlated with both strategy use and recall performance.

We conclude this section with a general comment. Many of the studies included here could be said to be "multiply-confounded," in the sense that the training packages include many components, e.g., extended practice, information about significance, information about effectiveness, general praise and attention, etc. As such, it is difficult, if not impossible, to ascribe benefits unambiguously to one factor or set of factors. Although this is of course a problem, it also represents one reasonable research strategy. Given that transfer is difficult to obtain, it makes sense to assemble a powerful package designed to elicit it. If the intervention is successful, follow-up studies can be designed to track down the more specific components responsible. Such tracking down is theoretically necessary. Regarding the implications for education, confounded treatments that work are extremely interesting in themselves. Clarification of the specific factor(s) responsible for positive effects may allow refinements of the package (Campione & Armbruster, in press), but an intervention that works (for any of a number of reasons) is a desirable outcome in its own right.

3. Self-Control Training Studies. The final category involves self-control studies, the main feature of which is the inclusion of explicit training of general executive skills, such as planning, checking, and monitoring. In the informed training approach, instruction of the target activities is supplemented with the provision of information about the activity and its effects. In self-control studies, the instructions include help with overseeing the activity.

Direct instruction of self-control skills should be particularly important in the context of transfer. For subjects participating in blind

training, the experimenter does the executive work, telling the learner what to do and frequently for how long to do it (Belmont & Butterfield, 1971; Brown et al., 1973). Self-control training can be regarded as an attempt to emulate more closely the activity of the spontaneous producer -- the trained subject is taught to produce and regulate the activity. Telling subjects to monitor and regulate their activities should produce the effects aimed at in informed training attempts; that is, if a subject does monitor his performance, he can see for himself that performance is improving, and he provides his own information about strategy effectiveness. To the extent that this occurs, training self-regulation might be expected to lead to more widespread effects than would the provision of information about specific strategies, because a consistent tendency to monitor performance would enable subjects to ascertain the effectiveness of a number of routines (see Campione, in press b).

Although there are fewer self-control training studies available than those from other categories, the initial results are encouraging. For example, in a series of experiments with mildly retarded children, Brown and her colleagues (Brown & Barclay, 1976· Brown, Campione, & Barclay, 1979) adapted the recall readiness paradigm employed by Flavell, Friedrichs and Hoyt (1970). The subjects were required to study a supraspan set of items for as long as they wanted until they were sure they could recall all the items. Baseline performance was poor and instruction was undertaken. In one condition, subjects were taught a rehearsal strategy to learn the list; in another, they were asked to anticipate list items before exposing them. In both conditions, the subjects were also induced to engage in self-checking activities to see that learning was occurring. The effects

of this strategy plus regulation training for a older group of subjects (MA = 8 years), but not for a younger group (MA = 6 years), were: immediate (1) beneficial effects of training, (2) maintenance of the strategy over a one-year period; and (3) evidence for generalization to a quite different task, that is, studying and recalling prose passages. The younger group showed only immediate effects of training: on maintenance probes, they reverted to baseline levels of performance, although mild prompts were sufficient to elicit the trained activities even one year later.

We would like to emphasize two points from this study. The first is that teaching strategy use in a fashion that also instilled self-checking or monitoring activities did lead to more impressive transfer performance than previously had been the case. Inclusion of executive control components in training is important. The second point is that these transfer effects were obtained only for the older group. To appreciate the developmental pattern a bit more, note that if we adjust performance for entering memory span differences, the older and younger groups did not differ prior to instruction. If we consider performance on unprompted maintenance tests later, there were large and significant differences between the groups. Thus, as in the Siegler (1976, 1978) experiments, the effect of providing training was to increase the difference between the older and younger subjects.

4. Summary. The series of blind, informed, and self-control studies leads to a number of conclusions. It is clear that the learning activities engaged in are an important determinant of performance, and that we can specify in some detail a number of those activities. We also see that the evidence indicates the existence of both specific sets of activities, which

are powerful but limited to a highly constrained set of circumstances, as well as more general ones, which are weaker but both broadly applicable and possibly necessary for the effective use of, or access to, the more specific routines. As we have begun to know more about essential processing components, we have become better able to program the student to execute them. Finally, for those effects to be obtained, it is not necessary that the learner be aware of what is being done to bring about learning.

That represents the good news, but there are also clear limitations. First, the beginning competence of the learner needs to be considered. Knowledge differences can limit the benefits that might result from inducing the subjects to carry out reasonable learning activities (Siegler, 1976, 1978). As Case (1978) has emphasized, it is also important to identify the particular strategies or approaches that students bring with them to the training situation. Examples of the importance of identification of entering states have been provided in Section III in the context of composing (Bereiter & Scardamalia, in press; Scardamalia & Bereiter, in press), summarizing prose passages (Brown & Day, in press), and scientific reasoning (Kuhn & Phelps, in press). Differences in functional memory capacity can also result in training programs that are successful with some students, but less so for others (Case, 1978).

Even in the best cases, where the learner can be led to use the activities to speed learning, the impact is lessened by transfer limitations. In this arena, recent research has resulted in some worthwhile results. One is that it is not difficult to get learners to maintain activities on new occurrences of familiar problem types. Also,

there appear to be considerable "savings." Mild prompts to use a previously taught strategy can result in its effective use (cf. Brown et al., 1979). Finally, as investigators have become more interested in programming transfer, rather than simply expecting it (Stokes & Baer, 1977), the evidence for transfer has begun to increase. In these efforts, the major factor has been an increasing attempt to foster the understanding of the specific skills being taught, both by providing knowledge about those skills (informed training) or by explicitly including general self-regulatory, or executive, functions in the tutorial interaction (self-control training). How effective these training attempts to orchestrate transfer will be in the long run remains to be seen, but the early results are encouraging.

C. Intervention Research: More Recent Questions and Emphases

In classifying the studies contributing to our conclusions thus far, the reader will note that they have involved almost exclusively young or poor learners in situations requiring deliberate memorizing or problem-solving. This feature of our review reflects the bias in the literature; the majority of the instructional work stimulated by cognitive developmental theory has featured this combination of learners and domains. Although we will speculate why this might be the case later, the obvious questions concern the extent to which the findings and conclusions can be generalized to situations involving older or more capable learners performing in other areas. We will deal first with the comparative/developmental issue, and then summarize some recent work on comprehension-fostering interventions. These discussions will be somewhat

brief, in part a result of the relative paucity of data. We argue that the overall patterns do generalize quite broadly and that the results obtained to date do indicate some areas where more work is needed.

A third issue is that of transfer, or more accurately, the difficulty of inducing learners to transfer the fruits of their learning experiences. In this context, we have discussed the role of more general learning skills in fostering learning to learn. We will return to a consideration of the general-specific tradeoff after discussing the developmental/comparative issues and work in the area of comprehension.

1. Developmental/comparative considerations. When young or poor learners are the targets of instructions to remember, it is clear that they need to be taught both specific powerful procedures and their overseeing and control. In the majority of training studies, only young or poor learners are involved. Although we cannot prove it, we believe this feature of the literature reflects the assumption that older or more capable learners already have or soon will have both the specific skills and the means for overseeing them. There are, of course, data consonant with this assumption. Although the memorization skills studied in the laboratory are not taught explicitly in schools, they are in fact acquired incidentally; and one outcome of schooling does appear to be the emergence and use of such learning activities (Scribner & Cole, 1973; Rogoff, 1981). Given this view, it is not necessary to teach such skills to developmentally more capable students.

There is, however, another possibility. More advanced students may not be as capable as this view would have us believe, with the result that they would also profit from instruction. Even if they do show evidence of

using memorization strategies, their use may be far short of optimal. That even highly selected learners are far from "expert" is clear if we contrast the performance of college students with that of expert mnemonists. More generally, there are increasing numbers of educators and educational researchers questioning the competence of college students' study skills (Chipman et al., in press). There is little doubt that there is still room for improvement.

Such speculation aside, the matter is an empirical one -- the necessary experiment involves instructing groups of learners differing in level of cognitive maturity, young versus old or less successful versus more successful, an instruction x levels factorial design. To illustrate the need for such designs and their potential complexity, consider the typical training study as it appears in the developmental literature. A young group of subjects, who initially perform less well than an older group, are given training on some process, the more effective use of which is presumed responsible for the developmental difference. Following such training, the performance of the young group improves, let us say to the level of the older group. One conclusion might be that the training was necessary for one group but not the other, the assumption is that training would have little or no effect on the efficient because they are already carrying out the trained process well. An excellent example of this approach is that of Butterfield et al. (1973) in which training of cumulative rehearsal resulted in bringing the performance of retarded adolescents up to the level of untrained adults and to the level of less stringently trained nonretarded adolescents. Note that the best learners in this example were not trained; we simply assume their ceiling performance.

An evaluation of that assumption requires that the older or more capable groups be given the same instruction. There are then a number of possible outcomes to the hypothetical expanded experiment. These different outcomes are of both theoretical and educational significance, because they indicate where remediation is or is not necessary and allow us to sharpen our account of developmental differences. We emphasize again that the interpretation of training studies, even the elaborated ones called for here, is not simple (Brown & Campione, 1978; Campione, in press a). To illustrate the various outcomes and indicate the types of information they can provide, we will describe five different patterns. Three involve relative convergence, in which developmental differences are reduced after training. A fourth is parallel improvement. And the final outcome is divergence, where instruction results in an increase in the magnitude of developmental differences.

Consider first a pattern of results that would allow the strongest conclusion about developmental differences and the assumed competence of older learners. In our hypothetical factorial design, age and presence/absence of instruction interact in the following way: instruction improves the performance of the younger but not older students, and following instruction, there are no developmental differences. A clear example of such a pattern was obtained by Brown (Brown, 1973; Brown, Campione, & Gilliard, 1974) in a judgment of relative recency task. There were no developmental differences between young and old on the task if there were no background cues to anchor the temporal series. If background cues were provided, however, the old capitalized on this information and outperformed the young. It seemed that the old, but not the young,

exploited the background cues and that this alone was responsible for the difference. Instructing students how to use the background cues did not change the excellent (but not ceiling) performance of the old, but it did succeed in bringing the young up to their level. This outcome is the strongest possible evidence that differential use of the trained component was the major, if not sole, determinant of developmental differences and that training was in fact unnecessary for the older.

A number of other outcomes involving relative convergence after instruction would also be informative. For example, instruction might affect only the young subjects, but their performance could still be poorer than the older students -- the implication here might be that the old are proficient with regard to the trained process and that there are additional sources of developmental differences involved in task performance. Alternatively, both the young and old groups might improve, but the younger might more so. The simplest conclusions in this case would be that the older subjects were not completely proficient in the use of the target process (else training would not help), that differential use did contribute to the original developmental differences (equating use did reduce those differences), and that there remain further sources of performance variations.

It is also possible, however, that training would have the same effect on both ages, i.e., in our Age x Instruction design, there would be two main effects but no interaction. Although there are a number of ways in which such interactions could arise, a simple interpretation would be that the process trained was important for performance on the target task, but that it did not contribute to developmental differences. As one example,

Huttenlocher and Burke (1976) set out to evaluate the hypothesis that developmental differences in digit span were due to the fact that older children grouped the input into richer "chunks." In a standard condition, they found the usual developmental differences. In a grouped condition, in which the input string was grouped by the experimenter to simulate the chunking presumably done by older subjects, both the young and old subjects improved, and to about the same degree. Thus, the intervention that might have been expected to reduce the developmental difference by being more effective or necessary for the younger group was equally effective for all subjects. Similar effects have been obtained by Lyon (1977) using college students who differ in terms of memory span. Interventions designed to reduce individual differences by providing "expert help" to the lower scorers improved everyone's performance and had no effect on the magnitude of individual differences.

A final possibility is that age (or ability) and instruction will interact, but that group differences will get larger rather than smaller. For example, young children may do more poorly than an older group before training, but after both groups have been trained, the difference may have increased. This "divergent effect" has already been noted in the Siegler (1978) and Brown et al. (1979) studies reviewed earlier, and is a far from infrequent finding (Cronbach, 1967; Snow & Yalow, in press). In fact, when performance in some open-ended domain is being investigated, it may be the modal outcome. The implication of this pattern would be that the trained routine was not exploited efficiently (if at all) by the more advanced students prior to training and that its use requires some additional skills or knowledge before it can be utilized to maximal effect. More capable

learners are better able to profit from incomplete instruction as they are more likely to possess those necessary resources (Campione & Brown, in press).

Some examples of this divergence have already been noted in the discussion of the Siegler (1978) and Brown et al. (1979) studies reviewed earlier. It is also important to emphasize that the particular pattern obtained in any study -- convergence, parallel improvement, or divergence -- can depend upon the criterion against which the training is evaluated. To illustrate this point, consider the Brown et al. recall readiness training study (Brown et al., 1979). Which of the three patterns best typifies the results? Recall that if we adjust for memory span differences, the MA 6 and MA 8 groups did not differ significantly prior to training. Immediately after training, the subjects were given a prompted posttest (on which they were told to continue executing the trained activity); both groups improved significantly, and there was still no reliable difference between them. Given these data, parallel improvement could be said to be the result. When unprompted tests were given a day later, however, the younger group abandoned the trained routines, and their performance reverted to baseline levels. The older subjects, in contrast, continued to perform well, and for the first time, there was a significant difference between the groups. If degree of independent (unprompted) learning is the criterial task, a divergent pattern is obtained. If we add to that the fact that the older children demonstrated transfer to a recall task, the divergent pattern becomes even more pronounced. Thus, even studies which produce convergence when initial response to instruction is the metric might turn out to produce a divergent effect if maintenance and

transfer probes are included (Campione & Brown, in press). To the extent that this is true, the frequency of these effects would be underestimated in the literature, as the majority of studies have centered on the immediate effects of training.

As Snow and Yalow (in press) have suggested, a divergent effect is a frequent finding. Our interpretation is that it indicates that advanced students can profit from some of the same, or at least similar, programs administered to less capable students. The kinds of instructional variables and interventions investigated with young and poor learners, far from being unnecessary or inappropriate with average to above average learners, may actually produce more pronounced benefits when applied to them. We will elaborate on this conclusion after considering some work in the area of comprehension.

2. Comprehension research. Although there has been considerably less relevant instructional research in the area of comprehension, we would argue that the patterns that are beginning to emerge are very similar to those in the memory area. We might first note that there is a good reason why there has been a relative lack of intervention research in this area -- we do not understand understanding as well as we understand deliberate memorizing. Whereas we can specify in some detail the activities and variables that can be expected to lead to durable memory of some set(s) of information, and can, thus, be quite explicit in terms of instruction, this is not true to the same extent for comprehension. Although it may be true that a learner need not be aware of a set of processes being employed in the service of memory or comprehension for those processes to produce the desired effect, it is much more difficult to see how a teacher could

transmit such skills explicitly if she is not aware of them. As more empirical and theoretical attention has been expended on comprehension processes (Spiro, Bruce, & Brewer, 1980), we have become better able to devise methods of improving students' ability to comprehend texts; and the number of instructional studies is increasing rapidly.

Before addressing the instructional research, we can note some high level similarities between the comprehension and memory areas. The tetrahedral model offered by Jenkins (1979) as a way of organizing the memory literature works equally well with only minor modifications when applied to comprehension (Brown, Campione, & Day, 1981). To illustrate some parallels, comprehension and recall of texts are influenced by the reader's activities, the reader's schematic and specific knowledge, and the interactions among these variables.

In this sphere of activities, Brown and Smiley (1978) reported that over a wide age range, subjects' ability to profit from a study period depended upon the study behaviors they displayed. Subjects, regardless of age, who demonstrated some appropriate study activity, either underlining or notetaking, recalled more on their second attempt; again age-independent, those who did not show evidence of such activities failed to improve from their first to second recall.

Regarding schematic knowledge, research inspired by the story grammar approach (Mandler & Johnson, 1977; Rummelhart, 1975; Stein & Glenn, 1979; Stein & Trabasso, in press) has succeeded in formalizing some of the structural properties of well-formed stories, properties that are appreciated by even quite young children. Texts that correspond closely to this structure tend to be more readily comprehended and recalled (Baker &

Stein, 1981; Mandler, 1979, this volume). Furthermore, as discussed in Section III.B, the availability of specific background knowledge influences both the form and amount of what is comprehended and recalled from a narrative, be the learner a college student (e.g., Sulin & Dooling, 1974) or a child (Brown, Smiley, Day, Townsend, & Lawton, 1977).

An example of a learning activities x knowledge interaction can also be found in the Brown and Smiley (1978) series of experiments. The ability of their subjects to profit from reasonable learning activities depended upon those subjects' ability to make use of specific knowledge about the domain being studied. Subjects who underlined or took notes during study did not benefit from those activities unless they were able to identify the main points of the story. That is, subjects at any of the different ages studied could profit from an additional study period only if they knew what the main points of the narrative were and engaged in an appropriate learning activity.

We can now turn to some of the parallels in the intervention research. Again, there are two major avenues open to those who would try to enhance performance -- modify the materials or modify the learner. Regarding materials, the data generated by the story grammar approach represent one relevant example. Stories written to conform to a canonical form are better understood than those that are not.

A second example of the modify materials approach, and an extremely popular one among researchers, is to provide adjunct questions to go along with the text (see Anderson & Biddle, 1975, for a review of much of this work). These questions can be inserted in various portions of the text, for example, before or after students read a particular text segment. We

can also distinguish different functions those questions might play. They might be expected to have either attention-directing or comprehension-inducing properties. Attention-directing questions would be aimed at specific points students are to master; they could, for example, be expected to help the students identify main points. Comprehension-inducing questions, in contrast, would represent attempts to increase overall comprehension scores, for example, by leading the students to engage in some "deeper processing" of the material being read. An attention-getting (adjunct) question would be "successful" if students were more likely to answer a subsequent (test) question on specific material than if it had not been highlighted during reading. A "successful" comprehension-inducing question would result in an increase in test accuracy on both items that had and had not been specifically questioned. As Anderson and Biddle (1975) report, the specific effects are much more impressive than the general ones.

One implication of these results is that such adjunct aids can be used to increase the likelihood that students know what the main points of the lesson are, an accomplishment that is far from trivial. The immediate benefit is that students are more likely to learn the important points given a single reading of the text than might otherwise be the case. An additional, and more subtle, outcome is that they should be in a better position to benefit from additional study than they would be without the questions. Recall that in the Brown and Smiley (1978) experiments, only students who were able to demonstrate that they could identify the main points of a passage demonstrated further gains in recall as a result of extra study time; simply rereading the passages produced no improvement. In these ways, attention-directing questions can be extremely helpful.

Note that the interventions aimed at the materials follow the general format of blind training studies. Stories are restructured, or additional questioning is provided, but the students are not taught to facilitate their own learning in situations where the narrative is not well-formed, or where helpful questions are not provided. In our view, these studies are aimed at facilitating learning of a particular text, but not learning to learn from texts in general (Bransford et al., 1981; Brown, in press a).

There are also a number of studies in which the main aim has been to modify the activities of the learner by teaching them some comprehension-related skills. One prerequisite of training studies of this type is the specification of the critical skills or activities in sufficient detail to enable an instructor to outline them to the student. We will use as an example training basic rules of summarization. Brown and Day (in press) described in detail the developmental progression associated with the use of five rules that were (in order of difficulty): (1) deletion of trivia, (2) redundancy, (3) superordination of examplars of a concept, (4) selection, and (5) invention of topic sentences (see Section III for a discussion). Day (1980) taught these rules to junior college students. The students differed in ability and in the type of instruction afforded them. The "control" treatment was similar to traditional summary writing instructions; the students were told to be economical with words, include all the main ideas, etc., but no further details were provided to help students follow these instructions. Another condition involved a listing and demonstration of the set of rules developed in the prior research (similar to informed training); and yet another included both the rules and explicit instructions regarding the managment and overseeing of those rules (self-control training).

Consider first only the highest ability group, students with no diagnosed reading or writing problems. Prior to training, their summaries were generally poor; they used the simplest deletion rules quite well but showed little evidence of use of the more complex rules. They did, however, respond to training and began to produce better summaries. Also of significance, the students continued to manifest this improvement in class assignments administered several weeks later by their teachers.

As with less mature learners in the earlier memory studies, it appears that these older students have not acquired some specific skills that are needed to facilitate performance in summarization tasks. Instruction based on an in-depth analysis of the underlying cognitive processes (Brown & Day, in press) does lead to substantial improvement. Consider also a comparison of the informed and self-control treatments. Differences as a function of instructional conditions were found, but only in the case of the most complex rule taught. For simple and intermediate difficulty rules (deletion, superordination and selection), informed training was sufficient to lead to maximal performance levels; however, for the most difficult rule, invention, use was better in the self-control than in the informed condition. When complex (for the particular learner) routines are being taught, inclusion of a self-control component appears necessary for optimal use of those routines.

Day (1980) also worked with students varying in ability. She included groups of junior college students who were average (in regular classes) or poor (in remedial classes) writers. For the simplest rules, nothing dramatic occurred; all students used those rules well prior to and following training. We will consider here only the more difficult rules --

superordination, selection, and invention. The ability groups did not differ significantly in their use of any of these rules prior to training. For the superordination rule, both groups improved, and to approximately the same extent; a pattern of parallel improvement was obtained. With the most difficult rules, a divergent ability x instruction interaction was found; although both groups improved significantly following training, average writers improved significantly more than poor writers. Thus, within this experiment, the form of the ability x instruction interaction varied as a function of rule difficulty. The more difficult the rule being taught, the greater the tendency toward a divergent effect. Day also included a group of students who were taking both remedial reading and writing courses. These more severely learning impaired students did not differ from the other groups prior to training, but the divergent effect was even more pronounced on, for example, the selection rule when tneir data were included. With the most difficult invention rule, these students with severe reading and writing problems did not improve at all, even after the most explicit (self-control) instruction. Overall, the tendency toward divergence increased as rule difficulty increased, and the magnitude of that divergence increased as the ability difference increased.

In summary, if we consider a number of instructional experiments which have included groups of students differing in age or ability and/or have involved manipulations of the complexity of the skills being taught, a general pattern begins to emerge. The most basic point is that poor performance often results from a failure of the learner to bring to bear specific routines of skills important for optimal performance. In this case, she needs to be taught explicitly what those rules are. This in turn

requires a detailed theoretical analysis of the domain in question; otherwise, we cannot specify the skills in sufficient detail to enable instruction. A second recurrent theme is that this requirement is more pronounced the poorer the learner, because the need for complete instruction increases with the severity of the learning problem.

Given that specific skills need to be taught, is it necessary for their teaching to be supplemented by the inclusion of more general self-control routines? One generalization that emerges is that the answer to this question depends upon the complexity of the routines being taught. We emphasize, however, that complexity is determined not only by the specific skills to be trained but also by learner characteristics such as prior knowledge, interest, overall ability, etc. Complexity does not reside solely in the skills but is an interactive function of the factors involved in the tetrahedral model. More mature learners already have some practice with executive/regulatory skills in other domains and hence are better able to supplement blind training regimes for themselves; but even in their case, as complexity increases, "metacognitive supplements" to instruction may be needed before optimal effects of instruction can be found.

3. General and/or specific skills? Throughout the discussion of training studies, we have made reference to specific and general skills, although we appreciate that the terms are problematic. Nonetheless, there are a number of important questions that arise in this context concerning the kinds of activities we should target for instruction. Should we teach specific skills, or general skills, or both? To reduce the ambiguity, we can refer to a helpful discussion of the general-specific issue provided by Newell (1979) He made use of an inverted cone metaphor, the base of which

contains many (hundreds?) of specific routines; these specific routines are also powerful ones. They are specific in that they are serviceable in only a highly limited number of cases; they are powerful in that once they are accessed, problem solution should follow (assuming only that they are executed properly). An example would be a task-specific rehearsal strategy. It is important to note that as we move up the cone, there is a tradeoff between generality and power. At the tip of the cone, there are a few highly general but weak routines -- general in that they are applicable to almost any problem-solving situation but weak in that they alone will not lead to problem solution. Examples here include exhortations to stay on task, or to monitor progress. These are weak in that, for example, merely noticing that progress is not being made or that learning is not occurring cannot rectify the situation unless the student brings to bear more powerful routines that can result in better learning.

In this view, one answer to the question of teaching general or specific skills is clear. Both types are necessary. If there are students who do possess most of the specific procedures needed for mastery within some domain, instruction aimed primarily at general self-regulatory skills would be indicated. It is in situations of this type that Meichenbaum (1977; Meichenbaum & Asarnow, 1978) has produced very impressive results. In contrast, there may be students who have internalized many of the self-regulatory routines and are highly likely to employ them whenever learning. What they may lack in a new problem are the powerful and specific procedures unique to that domain. As we have already discussed, the relative emphasis on general and specific skills in a particular case will vary as a function of both the ability of the learner and the complexity of the procedures being taught.

Within this view, we can characterize the research we have described thus far as involving very specific and very general skills. This general-specific dimension is also related to ease of transfer. Specific skills are powerful enough to enable problem solution *if* they are accessed; but the problem of access or transfer remains a major one. The executive, self-regulatory skills that are weak evade the transfer problem, as they are appropriate in almost any situation; no subtle evaluation of task demands is necessary. The result of including both types of skills in training programs is clear; use of the instructed activity is more effective on the original training task (cf. Paris *et al.*, in press), and there is evidence of increased transfer (cf. Brown *et al.*, 1979). Note, however, that the experimental work has involved single strategies and their use, not larger sets of specific skills -- and it is the latter case that is more typical of educational settings. For example, some reading programs involve upwards of 200 separate skills (cf. Campione & Armbruster, in press). Even presuming that the list could be dramatically reduced, the task of accessing, coordinating, and sequencing those skills remains a formidable one.

Rather than teaching a large number of specific routines and some extremely general supervisory ones, an alternative approach would be to identify and teach "intermediate level" skills, or packages of skills. These would be more general than the extremely specific routines investigated in much of the literature and taught in many school settings, but at the same time more powerful than the self-regulatory skills that have attracted so much recent interest. We will describe one example of a successful attempt of this type, and at the same time indicate some of the interplay between theory development and instructional research.

The experiment we will use, reported by Palincsar and Brown (1981) can be related to the adjunct question literature. One major difference is that whereas in prior research, the questions were provided for the student in an attempt to facilitate learning, Palincsar and Brown attempted to teach students to provide their own questions. In this way, they hoped to foster both learning and learning to learn. A second major difference is in the nature of the questions involved. In the adjunct question literature, the effects were extremely limited; students' learning of specifically questioned items improved, but the more general comprehension-inducing consequences were limited at best. This is not surprising in retrospect, as there was no compelling theoretical rationale underlying the construction and choice of questions. In fact, many investigators did not even believe it necessary to provide examples (Anderson & Biddle, 1979).

It is in the context of question generation that recent theoretical ideas become important. The notion that readers should engage in periodic self-interrogation while reading is not new, although it has become an even more common suggestion of late (cf. Baker & Brown, in press b; Brown, 1980, 1981; Collins & Smith, in press; Flavell, 1981; Markman, 1981). Of more direct interest are specific suggestions about the kinds of questions students should be taught to ask. Although the list is a long one, there is considerable agreement that the questions should both allow comprehension monitoring and facilitate comprehension.

To cite a few examples, Collins and Smith (in press) emphasize the continuous process of hypothesis generation, evaluation, and revision while reading. They distinguish between two main types -- interpretations and

predictions. Interpretations are hypotheses about what is happening now; predictions are hypotheses about what will happen next. It is clear that good readers engage in these activities while reading, just as they make and test inferences of many kinds (Trabasso, Stein, & Johnson, in press). They also engage in critical evaluation of ambiguous and contradictory segments of texts (Markman, 1981; Stein & Trabasso, in press). Poor readers are much less likely to generate these activities. Novice readers also experience difficulties with "lower-level" functions such as checking that they remain on task (Bommarito and Meichenbaum, cited in Meichenbaum & Asarnow, 1978) and simply paraphrasing sections to see if they understand and remember the gist of sections they have read (Brown & Day, in press).

As described in section IV, the training program devised by Palincsar and Brown was based on these analyses; and they set out to teach students to paraphrase and summarize sections of the texts they were reading, anticipate questions that might be asked, and predict what the author might go on to say next. As the results have already been described, we will simply mention that large improvements in comprehension and recall (500 - 600% increases on laboratory measures) were obtained, and that those improvements were found on passages that the students read <u>independently</u>, in both laboratory and classroom settings. Compared with the skills typically investigated in instructional research, teaching this routine was not easy. The instructor worked individually with students for many sessions, modeling the kinds of questions she wished students to produce and initially helping them formulate some of their attempts. Students were continually reminded of why these activities were useful, given feedback concerning their effectiveness, and told that they should engage in such

self-questioning any time they studied. Improvement took time, but eventually the students were able to generate appropriate questions without help. The return on the investment appears well worth the extra time and effort. The self-questioning approach is quite general, being applicable to a wide variety of texts. In this way, the transfer problem is in some sense "finessed," as the occasions for use of the instructed activities are quite clear.

D. The Problem of Transfer

We have spent considerable time talking about transfer and its importance to both developmental theory and educational practice. Throughout, we argued that major differences between young and old learners reside in their ability to access and flexibly use competencies they are known to possess (see also Brown, 1982; Brown & Campione, 1981; Flavell, 1982). Development consists in part of going from the context-dependent state where resources are welded to the original learning situation to a relatively context-independent state where the learner extends the ways in which initially highly constrained knowledge and procedures are used.

Transfer tests also play a central role in the evaluation of educational programs. For example, we are reluctant to say that someone has learned elementary physics or mathematics if they can solve only the problems they have practiced in class. Similarly, the ability to "read" one and only one text is not viewed as evidence of reading (except perhaps by some proponents of machine intelligence). No one would want to claim that a student had learned how to remember if the only data involved the student's ability to recite one set of materials that had been practiced frequently. Thus, the entire discussion of learning to learn is really a

discussion of the importance of transfer. In this section, we would like to elaborate upon our earlier discussions and deal with the transfer issue in more depth.

1. Relationships between learning and transfer. Our first point concerns the interdependence of learning and transfer. Consider some prototypical situations where transfer tasks are used for purposes of assessment. When evaluating training studies or school curricula, we frequently say that one method produced greater transfer than the other; similarly, we sometimes speak of individuals who "learned the training material but failed to transfer." Statements such as these can often be misinterpreted in that transfer is seen as some process that occurs after "learning" has taken place.

Imagine a situation where students practice until they are able to solve all the problems in a text (a statistics text, for example) and then receive new, but similar, problems on an exam. If they fail the exam, does it make sense to say that they learned but failed to transfer? It seems equally if not more appropriate to say that, in a very important sense, they failed to learn. Similarly, imagine that groups of children receive instruction on calculating the area of squares and triangles; some learn by memorizing formulas and others learn by "insight" (Resnick & Glaser, 1976). Imagine that the two groups now receive a new problem which requires them to calculate the area of a parallelogram and that the "insight" group does better. Has this second group "transferred farther" or has it learned different things?

It seems clear that the concepts of learning and transfer are closely interrelated (Brown, 1982; Brown & Campione, 1981; Campione, Brown, &

Ferrara, in press; Ferguson, 1954; Hebb, 1949). Furthermore, it could be misleading to assume that transfer is solely due to some process that happens after learning occurs. A major problem with the latter assumption is that it presupposes a unitary and clearcut definition of "learning," yet there are many ways to define learning. For example, Bransford (1979) describes the study activities of a student preparing for an exam in statistics. The student could solve all the problems on the study sheets and hence felt prepared for the exam. A friend cut out the problems from each sheet, shuffled them and asked the student to try again. This time the student failed miserably; he thought he had learned to solve the problems, but he was inadverently relying on chapter cues in order to choose the formulas and principles that were applicable to each problem. The student had learned something, of course, but he had not learned in a way that would allow him to function without the explicit use of chapter cues. (Note that the "experiment" conducted by the friend could have been done by the student herself. We will argue that such self-testing is the kind of activity that characterizes successful academic performers.)

Although it may be possible operationally to specify an "acquisition point," where some skill or bit of knowledge is originally acquired and a later transfer or "retrieval" point where that information is to be used, nonetheless it is a mistake to think of the processes involved as unrelated. What is learned and the related issue of how it is learned influence subsequent use. Indeed, one traditional use of transfer tests is to assess what it is that people have learned. And, the act of learning something new is itself a type of transfer task; people must activate potential skills and knowledge in order to understand and master new

content and principles. But this is not to say that learning automatically leads to transfer. When the new learning situation is introduced, it is frequently necessary for the student to search actively for the resources she has which are relevant to the solution of that problem (see Section III.B.2); both the tendency to search for, and the ability to find, appropriate resources are initimately involved in successful performance. To advance our theories of development and refine our educational programs, we need to identify the kinds of search and problem-solving strategies, both strong and weak, used by successful learners.

2. The Recognition of Problem Isomorphs. Many of the difficulties of transfer seem to involve the process of recognizing "problem isomorphs" (Brown, 1982; Brown & Campione, 1981; Gick & Holyoak, 1980; Newell, 1979; Rumelhart & Norman, 1981; Simon, 1979) -- recognizing that the new situation is similar to one encountered previously. For example, Gick and Holyoak (1980) presented college students with a task such as Duncker's (1945) radiation story. The problem is that a certain ray can destroy a malignant tumor. If the rays reach the tumor with sufficient intensity, the tumor will be destroyed. Unfortunately, at this intensity, healthy tissue will also be destroyed. The solution is to send the rays from different angles so that they meet simultaneously at the point of the tumor and hence summate to produce the required intensity. Healthy tissue is not destroyed because the single rays are not strong enough to do damage.

Students who had successfully solved this problem were given the structurally isomorphic problem of the attack-dispersion scenario. A fortress is located in the center of a country, many roads radiate from the fortress but they are guarded such that any large body of men attempting to

infiltrate the fortress would be apprehended. A general who wishes to attack the fortress must adopt the solution of dispersing his troops and sending them in small groups to meet at the attack point, the fortress. The disperse and summate rule is nearly identical to the rule required for the radiation-tumor problem.

In the absence of hints to use the preceding story to help them solve the new problem, students' transfer was less than impressive. Similar studies examining transfer between homomorphic or isomorphic versions of well-defined laboratory puzzle problems, such as missionaries and cannibals (Reed, Ernst, & Banerji, 1974) and Towers of Hanoi (Hayes & Simon, 1977), have also failed to find a great deal of spontaneous transfer. It should not be surprising, therefore, that young children also need hints that formally identical problems with different surface structures are indeed occasions for transfer (Crisafi & Brown, in preparation).

What is at issue in the recent research on problem isomorphs is a revival of the traditional Thorndike and Woodworth (1901) transfer theory of identical elements. They argued that transfer will occur across tasks only to the extent that the tasks share identical elements. Some version of identical elements theories has persisted (Ellis, 1965; Gagné, 1967; Osgood, 1949). Thorndike and Woodworth defined identical elements primarily in terms of physical features of the task. But as an earlier identical elements theorist, Hoffding (1892), pointed out, the real problem with transfer lies not in the physical dimensions of the task environment but in the perceived similarity of task domains as constructed by the learner. Hoffding's position is very similar to contemporary theories of tranfer of training. In additional to noting that degree of physical

similarities among task context can determine transfer, Hoffding was concerned with perceived similarity between situations; how new situations elicit old responses, how a new situation comes to be connected with the stored trace of previous learning, i.e., the famous Hoffding step (1892) that is still in its many guises a central problem for psychology.

Common elements may be the key to transfer, but they are difficult to define. And if people use the wrong elements for classifying the current situation, one would expect many errors. Studies of expert versus novice problem solvers suggest that the "elements" used to recognize problem types can have important effects on performance. For example, novices tend to use key words in the problem format when they are asked to sort problems into types; in contrast, experts generally sort on the basis of underlying conceptual identities (Chi, Feltovich, & Glaser, 1981; Larkin, Heller, & Greeno, 1980; Simon, 1979). An important outcome of increasing expertise within a domain and an important determinant of transfer may, therefore, involve the ability to recognize the appropriate types of commonalities; otherwise, a problem may be misclassified and hence approached in an inappropriate way.

Assumptions about the importance of recognizing that a new situation is similar to old ones seem to underlie many methods of training. When we explicitly "train for transfer" we often try to help people learn to identify appropriate "elements." For example, "training in multiple contexts" is a principle that is endorsed by many theorists because it decreases the likelihood that a particular piece of information will be welded to a particular context, and hence it increases the probability of performing well on transfer tasks (Belmont, Butterfield, & Borkowski, 1978;

Brown, 1974, 1978; Brown, Campione, & Day, 1981). Similarly, the practice of encouraging learners to state a general rule is effective in inducing transfer because it highlights that general rule and makes it explicit (Gagné & Smith, 1962; Thorndike & Stasz, 1980). Training in multiple contexts with explicit statements made concerning the general rule increases the probability of effective transfer.

Related examples of training for transfer involve what Feuerstein and colleagues (1980) call "bridging." Students may learn a general principle and then be helped to see how it applies to particular situations such as social problem solving, learning mathematics and so forth. That is, explicit instruction is given in the range of applicability of the concept (Brown, 1978; Brown & Campione, 1981). The assumption underlying bridging is that the children need to see how particular principles apply to new situations; otherwise, they may fail to utilize the principles in these situations.

To summarize, the preceding examples suggest that "problem recognition" plays an important role in transfer. If people are unable to see how a new situation is related to ones previously encountered, it is difficult to imagine how transfer could occur. When we "train for transfer" we are implicitly acknowledging the importance of problem recognition; people who are simply asked to memorize principles, formulas or concept definitions or who learn a strategy only in one context may not recognize that these are applicable in other situations. By illustrating a variety of situations or contexts in which learners may profitably use their knowledge and strategies, we are increasing the probability that transfer will occur.

3. Static vs. dynamic approaches to transfer. In many of the examples we have discussed, the aim is to modify instruction to lead to transferrable learning products. Training in multiple contexts, for example, is designed to teach not only a rule (strategy, bit of knowledge, etc.), but also to provide information that the rule is of somewhat general use. Further, an attempt is made to illustrate something about the range of applicability of the rule in question. Seeing the rule applied in several contexts allows the learner to understand its significance and to infer some of the properties of situations in which it is applicable. The rule thus learned has become in some sense a "transferrable" item in the learner's knowledge base. We see this as a static aspect of transfer. The learner has acquired a resource that can be brought to bear in a number of situations; when those situations appear, she is likely to access the specific rule and, thus, perform well.

There is, however, another aspect of transfer we would like to emphasize. We can consider situations in which specific resources necessary for problem solution are not in the learner's repertoire and ask what, if any, transfer might be expected in that case. To be more concrete, the present authors would be unable to solve numerous physics problems because we lack the content knowledge necessary to do so; in this situation, whatever general skills and strategies we possess would do us little good. Should one, therefore, conclude that there is no transfer from the present author's area of psychology to many areas of physics? Our answer is that it depends upon the approach to transfer that one takes.

The transfer task just described (asking psychologists to solve physics problems) represents a static approach to transfer; the basic

question being addressed is "What do these psychologists know at this particular point in time?" This is very different from the question: "Can these psychologists learn to solve physics problems?" From the perspective of this dynamic approach, there can be transfer from psychology to the physics domain.

Recently, one of the present authors (JDB) decided to learn about a new area of physics and to keep a log of the experience. A physicist picked a particular topic and supplied relevant material to be read. The psychologist found the task difficult but it seemed clear that there were many general skills and strategies that facilitated learning. These included (a) a general sense of what it meant to understand something rather than merely memorize it, (b) the ability to recognize that some texts were more advanced than others and that the advanced texts were not the place to begin, (c) the ability to recognize when certain technical terms were crucial and needed to be understood more adequately, (d) knowledge of the need to search for relevant examples of certain concepts and principles that were defined abstractly in a particular passage, (e) knowledge of the importance of removing examples and example problems from the text context, randomizing them, and seeing if one really understood them, (f) the ability and willingness to formulate questions to ask a physicist when the texts would not suffice, and (g) the ability to determine whether the physicist's answers to those questions made sense (to the learner, that is).

Perhaps the most important information available to the experienced learner was that the texts were objectively difficult, fault did not rest with his learning potential but with inadequacies in his background

knowledge. The learner was, therefore, willing to ask questions of the expert rather than give up the endeavor for fear of seeming stupid. In general, the learner knew something about how to learn and hence was aware of the difficulties to be expected as well as some of the mistakes to avoid (merely memorizing rather than trying to understand, looking up each and every unknown word, placing equal weight on all concepts, for example).

Note that the psychologist's knowledge of how to approach the problem of learning new information could not be tapped by a static measure that simply assessed the ability to solve physics problems. The psychologist lacked information necessary to solve these problems; if this information is not available in the testing environment it is impossible to assess the degree to which someone is able to use it in order to learn. Questions about learning and transfer require a dynamic approach (Brown & Ferrara, in press).

Both the static and dynamic approaches to transfer are important and valid; we sometimes want to assess what someone knows (static approach) and at other times to assess what they can learn (the dynamic approach). For example, most current measures of achievement are static measures that assess the current state of people's knowledge and skills. This information can be important and useful; we often need to know whether a learner has the necessary skills and knowledge for handling a particular course or job. It would be unwise for a physics department who needed an expert in astrophysics to hire our psychologist who knows no physics "because the psychologist knows how to learn." Even efficient learners would require too much time to develop the necessary expertise; expertise takes time to acquire (Simon, 1979).

There are other situations where the static approach becomes much more questionable, where we use static measures to make claims that actually require the dynamic approach. Measures of "intelligence" are a prime case in point. Like achievement tests, most intelligence tests are also static measures of an individual's current level of skills and knowledge. However, when interpreting intelligence tests we tend to translate a static score into a ranking number (e.g., IQ = 92) that is assumed to "hold for all time."

We argued earlier that a static test makes it difficult for us to measure people's abilities to learn to perform more adequately. Imagine that we give a physics test to our psychologist who know no physics (but knows how to learn) and compare his performance with student who has muddled through one course in physics but does not know how to learn efficiently. The physics test may reveal that student X is much "better" than the psychologist, but this tells us nothing about the latter's abilities to learn physics; indeed, the learning skills of our hypothetical psychologist may be far superior to student X. If we used the initial test to measure the "intelligence" of the two individuals we would be using a static test to make a claim that actually requires a dynamic test.

Of course, creators of general intelligence tests do not use items such as those found on physics tests because they know that people differ greatly in terms of their experience with physics concepts. Intelligence tests are, therefore, putatively composed of "familiar" items that everyone should have had an equal opportunity to learn or that are relatively unfamiliar to everyone. Needless to say, there are many debates about whether these conditions can ever be met, thus, we may always face some

version of the psychologist-person X problem when using static measures. However, imagine that we could ensure that everyone had had equal exposure to information required for answering questions on an intelligence test. We could then assess the degree to which people were adept at learning from their experience; however, the fact that Person A learned less from her experience than Person B does not mean that Person A cannot learn how to learn. If one is interested in learning potential, the problem requires a dynamic rather than static approach (Brown & Ferrara, in press; Feuerstein, 1980).

This brings us back to one of the questions we raised at the outset of Section V. Are there general learning skills, and can and should they be taught? We believe that the answer to each question is yes. Efficient learners bring to bear on typical learning situations a number of resources that facilitate learning in new domains: they have learned to learn. They tend to profit more -- learn more rapidly and transfer more broadly -- than poorer learners from objectively identical learning situations because they know more about learning and supplement for themselves the information afforded. They apportion effort appropriately, continually monitor progress, know when and how to seek advice, etc.

Efficient learners also prepare for transfer and engage in sophisticated reasoning aimed at accessing and using current knowledge. They prepare for transfer, for example, by regarding "new" problems, not as isolated ones, but as instances of a general class (e.g., Scribner & Cole, 1973); they expect that what they learn may be relevant elsewhere and entertain hypotheses about where and when. Simply knowing that transfer is desirable from prior situations to the current one, or from the current one

to future ones, is itself part of the battle. Good learners perform thought experiments, seek appropriate analogies and understand some of the principles involved in learning and reasoning from incomplete knowledge (e.g., Collins, Warnock, Aiello, & Miller, 1975). To repeat, good learners supplement incoming information in a number of clever ways to facilitate their own learning. Instruction may well be incomplete, but they have the skills to "complete" it for themselves.

We conclude this section by noting that these skills tend not to be taught explicitly, and that there is growing evidence that even many college students do not acquire them incidentally (Chipman et al., in press). Given this growing awareness, fostered in large part by basic research efforts, it is not surprising that this situation is changing, and the amount of attention devoted to teaching "cognitive skills" is increasing.

E. Beyond Cold Cognition

In this section, we would like to emphasize that there is more to effective learning to learn than the issue of how instructors should impart "pearls of cognitive wisdom." Important factors involved in learning to learn are emotional as well as strictly cognitive. Poor performance can be due to objective facts such as deficient materials, inappropriate learning activities, or unexpected criterial tasks. But many children may add to their difficulties by attributing their poor performance to themselves (to their "lack of intelligence," for example) rather than to other factors in the tetrahedral framework (Diener & Dweck, 1978; Dweck, companion volume). Variations in opinions about oneself as a learner seem to be extremely important for understanding normal and atypical development and for

designing programs that might help students learn to learn more effectively.

Virtually everything we have discussed so far involves what many would call the "cold cognitive" aspect of learning (Zajonc, 1980). But there are other dimensions to learning that are extremely important; for example, people have feelings about particular learning tasks and about themselves as learners that can have pervasive effects on their performance (Bransford, 1979; Brown, 1978; Henker, Whalen, & Hinshaw, 1980; Holt, 1964). Some individuals may be convinced of their inability to learn mathematics, for example (Tobias, 1978), or of their incapacity to solve certain types of problems. Some children actively resist learning because their peers think it inappropriate or demeaning (McDermott, 1974) or because of their own diagnosis of personal incompetency. A particularly sweeping self-diagnosis was given by Daniel, a learning disabled ten-year-old, who worked with the first author. Upon encountering his first laboratory task, Daniel volunteered this telling comment: "Is this a memory thing?" (it wasn't) -- "Didn't they tell you I can't do this stuff?" -- "Didn't they tell you I don't have a memory?" Given this devastating estimate of his own ability, it is not surprising that Daniel would be diagnosed as passive, even resistant in situations that he classifies as tests of his non-existent faculty. It would take many sessions of systematically mapping out the specific nature of his memory problem, providing feedback about just where the problem was acute, but also where there were no problems at all, before Daniel could derive a more realistic evaluation of his learning problem, and as a consequence, would be willing to attempt active learning strategies, to overcome a recognized problem.

It is by no means difficult, therefore, to imagine ways that negative feelings about a task or about oneself can affect learning. Nor is it surprising that people tend to avoid situations that tap their area of weakness, thus conspiring to provide themselves with less practice in areas where it is most needed. Teachers inadvertently conspire to help students do this by, for example, addressing questions to students capable of answering and passing by those that need help, to save everyone embarrassment. For example, recent observations of reading groups (Au, 1980; McDermott, 1978) have shown that good and poor readers are not treated equally. Good readers are questioned about the meaning behind what they are reading, asked to evaluate and criticize material, etc. By contrast, poor readers receive primarily drill in pronunciation and decoding. Rarely are they given practice in qualifying and evaluating their comprehension (Au, 1980). There is considerable evidence that teachers give less experience in this learning mode to those who, because of their lack of prior experience, need it most (Gumperz & Hernandez-Chavez, 1972).

A plausible emotional block to effective learning involves an inefficient use of limited attention because a significant amount of cognitive effort is being directed to self-defeating, anxiety-producing, self-evaluation. If learners focus on thoughts such as "I can't do this" or "I'm going to fail again," they will not be able to attend to the details of the actual problem. Such negative ideation (Meichenbaum, 1977) can have a paralyzing effect on learning (Dweck, companion volume).

Another related block to learning includes a lack in the confidence necessary to debug one's own errors. Some learners may not be sufficiently

secure to enable them to tolerate mistakes; hence, they may ignore any errors they make, or forget about them as quickly as possible (Bransford, 1979; Holt, 1964). Others may refuse to take the risk of responding incorrectly and hence be deprived of valuable feedback. It seems clear that the "cold cognitive" aspects of learning are only part of a much larger system that influences development; indeed, the purely cognitive aspects may be less primary than we like to think they are.

F. Beyond Isolated Cognition

In this last section, we would like to stress that learning is not only a less purely cognitive activity than we often suppose; but it is also a less individual activity than might be readily apparent from a consideration of learning studies. We do not have space to deal in depth with this issue, but an excellent treatment is given in the Laboratory of Comparative Human Cognition chapter in a companion volume to this. Here we will discuss only one issue to illustrate the importance of social mediation in learning. We will concentrate on tutors as agents of change in cognitive development (see also Section IV.B).

In our previous discussion of training studies we portrayed parents, teachers, and researchers as dispensers of "pearls of cognitive wisdom." Effective mediators do much more than focus on particular concepts and strategies that may improve task performance; they respond to individuals who may feel confident, anxious, enthused, threatened, defiant and so forth. Cognitively oriented developmental researchers who derive most of their developmental information from laboratory tasks often deal almost exclusively with relatively "enthused" individuals (Bransford, 1981). Good experimenters go to considerable lengths to design experiments that are

interesting and non-threatening; they attempt to structure the situation in ways that will minimize potential problems of "hot" cognition. This strategy is both practical and humane, of course, but it can also lead researchers to overlook emotional resistance to learning because they rarely confront it in their experimental work (Bransford, 1981). In addition, many of the experimental procedures for insuring cooperation, enthusiasm, and so forth are relegated to the domain of "lab lore" rather than viewed as an integral part of a theory of development. As researchers, we routinely use our intuitions to structure "optimal" learning environments, yet give little thought to the fact that the learner and experimenter are interacting within the confines of that environment. If the situation were changed, if we were unable to convince people to cooperate in a training study, for example, any pearls of cognitive wisdom we wished to offer would have very little effect.

The literature on parent/child interactions provides illuminating examples of the social basis of teaching and learning. The basic unit of learning and teaching is one of dialogue (both verbal and non-verbal) rather than a monologue (Schaffer, 1977, 1979; Vygotsky, 1978); children and their mediators influence one another and make mutual adjustments. For example, effective mediators use feedback from the learner in order to determine whether to repeat an instruction, put the instruction into simpler words, and so forth. Effective mediators estimate the child's "region of sensitivity to instruction" and work from there (Wood & Middleton, 1975); even teachers who seem to be lecturing in a monologue attempt to anticipate the needs of their audience and make use of student feedback.

Many of the activities employed by effective mediators are specifically focused on "cold cognitive" aspects of instruction, on particular concepts, factual knowledge, or strategies, for example. But effective mediators do much more than impart cognitive lore. They encourage children, try to help them stay on task, express joy at the child's accomplishments, and so forth. Learning proceeds smoothly when child and mediator are in "synchrony" (Schaffer, 1977, 1979). But, it is often very difficult to establish and maintain this synchrony; many of the moves made by effective mediators are designed to do just this.

To give one example, a side benefit of the zone of proximal development testing procedures being developed (Brown & Ferrara, in press; Campione, Brown, & Ferrara, in press) is that of increasing the child's feelings of competence. The procedure is such that if children fail to solve a problem unaided, they are given a set of increasingly explicit hints toward solution. The interactive and collaborative value of the adult/child relationship is such that the children believe that they are collaborating in the problem solving process. Even when the adult provides such explicit clues that the answer is virtually given to the children, the prior collaboration leads the children to maintain faith in their own vital part in the learning solution. They seem to feel they have worked towards a solution that they eventually discover for themselves (Brown & Ferrara, in press). This interpretation was not generally made by a group of elderly women who took part in a similar zone of proximal development study (French, 1979). Threatened by the test-like problems, and deeply unsure of their own cognitive competence, the women interpreted the hints as a indication of their failure. Help often had to be terminated after two or

three hints as the situation became intolerable. These data point out the importance of the learner's attitude in training studies and testing situations. Having in general a healthy self-image, academically successful children are able to capitalize on hints even when given inadvertently in standard testing situations (see Mehan, 1973). Children who have already experienced more than their fair share of academic failure often fail to benefit from such aid because they are too busy covering up their supposed incompetence.

Mediators vary in how effectively they can establish the necessary empathy so that learning can occur. The present authors have had the opportunity to observe video tapes of Feuerstein (1980) working with academically less successful adolescents. Feuerstein is a gifted clinician, a "cognitive therapist," if you will. He does a great deal of prompting in order to help children improve their approaches to various academic problems, but this is only part of his function; many of the moves that he makes are designed to alter the child's general reactions to the situation and the task. For example, one child faced with her first figural analogy problem said, in an extremely agitated and whiney voice: "I can't do that! I'm not used to that kind of problem." Feuerstein's response was: "Of course you can't do it -- yet. Nobody can do things well until they have learned them. You can learn to do these problems, and I'm going to help you learn to do them." The girl did indeed learn to solve the problems (much to her amazement as well as her parents'); furthermore, the session ended with the girl demanding to be given more problems when Feuerstein decided that it was time to stop.

Note that the moves Feuerstein made were designed to alter the student's reactions to the situation; to move her from a whiney "resistive state" dominated by negative ideation (Meichenbaum, 1977) to a more positive self-appraisal. Feuerstein did much more than simply dispense "pearls of cognitive wisdom." The literature in clinical psychology contains some valuable information that is relevant in this context; for example, Strupp and his colleagues (Strupp, 1980 a,b,c; Strupp & Hadley, 1977) discuss the importance of developing a "working alliance" and Horowitz (1979) analyzes the importance of helping clients move from "resistive states" to "working states."

Feuerstein's success has been criticized on the grounds that "it's all Feuerstein." A similar argument is that children learn simply "because of good teachers" or that clinical therapy works "because of gifted therapists." The assumption behind such criticisms seems to be that some mediators are "gifted" or "magic" and that is all there is to it. Much of cognitive development is an inherently social phenomenon that depends on effective mediation; it is not then sufficient to simply assume that some mediators are "magic" or "gifted" and some are not. In their fascinating book, The Structure of Magic, Bandler and Grinder (1975) analyze the procedures used by successful therapists in order to make their procedures more explicit and hence learnable by novices. Similar analyses of the methods of effective agents of change, be they teachers, tutors, mastercraftsmen, priests, politicians or clinicians, represent important activities for cognitive psychologists. The recent attempt by Collins and Stevens (in press) to seek regularities in the activities of a variety of outstanding Socratic teachers is an important contribution to the literature.

There is an everpresent conflict faced by mediators, a conflict between their "humanitarian side" and their "cold cognitive" side. Mediators hesitate to push too hard for fear of making learners anxious and unhappy (sometimes rebellious, perhaps). But, the failure to push at all may protect the child from learning something new. Effective learning environments are those where the "humanitarian" and "cold cognitive" side of mediators are not in direct conflict. Many of the moves made by successful mediators can be viewed as attempts to create and maintain a balance between these two dimensions. If the balance is not developed and maintained, effective mediation does not occur.

There are many things that mediators do intuitively that eventually need to become part of a comprehensive theory of learning. When working with less successful students who are anxious about being tested, an effective mediator may adapt the role of helper or benefactor rather than "tester." There are other common ploys that enhance learning. For example, rather than emphasizing the student's ability (or inability) to remember information one can focus on the degree to which the material is easy or difficult. Students then focus on evaluating the material rather than themselves and are open to suggestions concerning methods of making difficult materials easier to learn. Similarly, the ability to detect errors in one's own work and then make revisions can be viewed as a positive achievement rather than a sign of failure.

One of the most important aspects of effective mediation may involve procedures that enable children to experience a sense of mastery, that let them see that they have some control over learning situations and that systematic analysis can lead to successful performance. An important

outcome of such mediation may be a more positive attitude toward the general task of learning and problem solving and toward one's self as a learner. These outcomes may be as important as "number of problems solved successfully" although one would hope that they would be positively correlated. Successful mediation involves much more than the act of dispensing "pearls of cognitive wisdom." Successful researchers in cognitive development implicitly know this, of course, and use the information to design effective experiments and training studies; but it is important to move this knowledge from the domain of "lab lore" to the domain of theory. If we do not, we may be ignoring some of the most important influences on development that exist. The emotional cannot be divorced from the cognitive, nor the individual from the social.

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FOOTNOTES

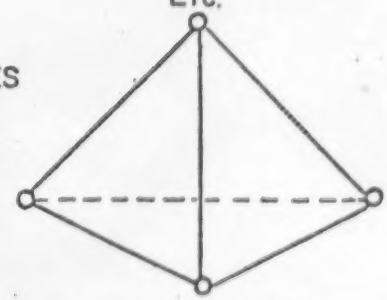
1. A considerably expanded version of this section can be found in Brown (in press b).

Figure Caption

Figure 1. A Simple Learning Model

AN ORGANIZATIONAL FRAMEWORK FOR EXPLORING QUESTIONS ABOUT LEARNING.

(Adapted from Jenkins, 1978 and Bransford, 1979.)



CHARACTERISTICS OF THE LEARNER
Skills
Knowledge
Attitudes
Etc.

LEARNING ACTIVITIES
Attention
Rehearsal
Elaboration
Etc.

CRITERIAL TASKS
Recognition
Recall
Transfer
Problem Solving
Etc.

NATURE OF THE MATERIALS
Modality
(visual, linguistic, etc.)
Physical structure
Psychological structure
Conceptual difficulty
Sequencing of materials
Etc.